Quantum Optical Mechanics (QOM)

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ABSTRACT

This is the sixth report on a new research programme investigating the electromagnetic (EM) interaction. This paper analyzes the effects of interactions arising from multiple, remote electrons on one or several, local 'target' electrons. These interactions are the result of the **new quantized form of the EM impulse** introduced in the previous paper.

This model is used to re-interpret various optical effects that have previously required the existence of a fundamental object known as '**LIGHT**': a basic entity, considered to be either a particle **or** a wave (**or** even both? - the '***photon***') that **travels** across space. In contrast, this new EM model is constructed upon the key role of the 'light' emission processes, categorized as either oscillatory (as in antenna) or transitory (as within atoms). These real emission processes are now integrated into the asynchronous ***action-at-a-distance*** model of the EM interaction that is the basis of this new theory. Mathematically, this new model describes algebraically how variable or periodic phenomena (that have been assumed require the use of waves) can be explained by periodic, asynchronous, remote interactions between point particles without any use of differential equations (including the wave equation). This paper now extends the earlier pair-wise interaction between two electrons into the **many-body** world of macroscopic reality. The two key ideas of interaction **saturation** and **selection** are now introduced, which totally differentiate this theory from all other theories constructed around universal, continuous interaction (or '**force**') models. By eliminating all the ray, wave and photon models of 'light' this paper now extends the original Newtonian mechanical *philosophy of nature* to the major domain of optics: both classical and quantum. The emphasis is on the **electrons** and on the relationship *between* electrons and **not** on some hypothetical 'carrier' that travels between them – this is the **Newtonian** action-at-a-distance particulate model extended to multiple times. The idea of selection leads to the introduction of information waves that identify the location and velocities of **all** other electrons that *might* participate in a ray-like exchange of momentum between pairs of electrons (saturation) that always act like particles (real trajectories across space). These supra-luminal waves do not carry momentum but ensure that the interaction minimizes the exchange of **action** across a non-local region of space. **This new model resolves the long-time paradox of electrons as waves or particles**: electrons are seen here as real point particles that interact periodically (rather than continuously) together; the focus is on the relationship **between** them that can be described by the discrete mathematics of particles or the periodic mathematics usually associated with waves. This paper includes the **first** analytical solution to the 3D scattering of two electrons – in the center-of-mass frame of reference both electrons are shown to go in quantized spiraling, conical motions: towards each other and then away from each other.

The present theory provides an alternative to Feynman's mathematical approach to "*the mysterious properties of light*" while providing a physical explanation for some of the calculational diagrams introduced by Feynman in his approach to quantum electrodynamics (**QED**). This now replaces **all** field theories of 'light' without introducing the concept of the photon or virtual particles and so eliminates all QED **infinities** in the physical properties associated with the interactions of electrons arising from the false idea of vacuum polarization, returning the vacuum to its Newtonian role as the **passive**, empty space between real particles. This **new EM theory** establishes a firm foundation for a new quantum theory that covers all scales of nature from the macroscopic to the heart of the atomic nucleus, while covering the complete range of interaction sets from a pair of electrons to the myriads of electrons existing in macroscopic objects.

The next (companion) paper will explain the wave-like properties of electrons while providing a new, comprehensive theory of quantum measurement. This next paper will finally establish the critical link between the realistic model of the micro-world introduced so far and the macroscopic world of scientific measurements.

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1. INTRODUCTION & OVERVIEW

1.1 INTRODUCTION

A New Theory of Light

This is the sixth report on a new research programme investigating the electromagnetic (EM) interaction. This paper analyzes the effects of interactions arising from multiple, remote electrons on one or a few 'target' electrons. These interactions are described by the new quantized form of the EM **impulse** introduced in the previous papers in this series combined with the hypothesis of interaction saturation introduced in the present paper. Earlier papers in this series have discussed various phenomena involving light but that was not their principal focus. The present paper returns to classical electromagnetism (CEM) but now the focus is on re-interpreting the role of CEM in providing only a foundation for the classical wave theory of light with a new theory that **also** explains the discrete phenomena of light. The history of physics shows that the roots of both quantum mechanics (QM) and quantum electrodynamics (QED) lie deep in the soil produced by 19^{th} Century optical experiments. The so-called **duality of light** (involving both discrete and continuous properties) led directly to similar contradictory concepts being associated with the particulate electron. This paper will show that these duality contradictions can be replaced with a unitary view of light by focusing on *the interaction **between** pairs of electrons*. These ideas will be developed much further in the next paper where the focus will be on the repeatable interaction between macroscopic collections of electrons and individual electrons – this will provide a new alternative to the so-called '*measurement problem of QM*'.

Light's Fascination

Light has fascinated physicists since *Traite de la Lumiere* was published in 1678 by Christian Huygens (1629-1695) followed by *Opticks* published in 1704 describing the researches on light by Isaac Newton that he had worked on from around 1670.

'What is Light?'

The authors of the entry on '**light**' in the 1971 edition of the *Encyclopedia Britannica* acknowledge that: "since light is one of the basic existents in nature they cannot offer a deeper explanation beyond an enumeration of its properties and its mathematical characteristics"; they admit to appealing to analogies and models to help with understanding. Unfortunately, as they admit: "this is never enough, for though logic indicates proper deductions it fails to specify what will be interesting and what direction the theory will take." This research programme will take direct issue with this far too common retreat into phenomenology and will show that there are, indeed, more fundamental ways, in which to view this key subject. Indeed, Pauli recalls Einstein frequently saying to him: "For the rest of my life, I will ponder on the question of what is light?" As one of the premier historians of quantum physics, Max Jammer wrote so poetically: "Light, although the principal agent of our knowledge of the external world, has never revealed its own identity and has never removed the veil of its mystery."

1.2 OBJECTIVES

The principal objective of this paper is to present an alternative theory to the disparate collection of theories that have been used to provide explanations for the various phenomena known as 'light'. The key insight is to analyze how differing numbers of electrons interact at remote separations. The objective here is to create a unitary theory of optics that eliminates the two contradictory concepts of wave and particle that distorted the quantum theory from its very beginnings.

1.2.1 STATISTICAL ELECTRON INTERACTIONS

The main approach of this paper is to develop a detailed model of how **very many** electrons interact at **large** distances and **all** speeds. This model is used to re-interpret various optical effects that have previously required the existence of a fundamental object known as 'light': a basic entity considered to be either a particle or a wave, or even both (the '***photon***'). A secondary objective is to show algebraically how periodic phenomena (that have required the use of waves) can also be explained by periodic, asynchronous, remote interactions between point particles without any use of differential equations. This extends the Newtonian (mechanical) philosophy of nature to the central domain of optics.

1.2.2 EXPLAINING THE 'WAVE' NATURE OF LIGHT

One of the over-arching objectives of this research programme is to demonstrate that the phenomenological approach is inadequate as a fundamental explanation of the micro-world. Modern physics began around 1700 with attempts to create concepts that would explain the behavior of nature – sometimes these conceptual models could be given a mathematical form so that numerical values could be obtained which could then be compared with experimental measurements. This view increasingly became the only scheme that physics would allow. When statistical variables, like temperature, were modeled mathematically, it became possible to invent simple equations describing the relationships between some of the macroscopic variables that were directly amenable to measurement. Unfortunately, this phenomenological approach was extended to the micro-world and equations were constructed in terms of variables that had no direct experimental analog, so that no conceptual model could be developed. Equations were constructed to describe distinct groups of experimental results but these equations could not be combined into a single, conceptual scheme. Each equation-set had its own distinct concepts and these were in conflict with each other. This led to the compromise that nature at the micro-world was too 'weird' to be understood by humans with their senses (and concepts) developed at the macro-level. This paradoxical situation has resulted in an impasse at the fundamental level because the power of the human imagination can rarely be brought to bear without use of coherent visual imagery. This paper addresses this broad class of problems that have required the conflicting ideas of particles and waves to be used when describing mathematically optical phenomena and its fundamental construct: "light". This dual nature of light stimulated the development of wave mechanics, moving theoretical physics even deeper into the "swamp of confusion".

1.2.4 ELECTRON INTERACTION VIEW OF THE 'PHOTON'

The final objective of this paper is to identify those conditions in the model of interactions between electrons that represent the discrete phenomena of light that have been hidden by introducing the particulate concept of light itself (the 'photon').

This paper provides the basis (in the next paper) for a replacement for quantum electrodynamics (QED) without introducing the concept of the photon or virtual particles and thereby eliminates all QED infinities. This theory is designed to establish a firm foundation for a new quantum theory (in subsequent papers) that covers all scales of nature from the macroscopic to the heart of the atomic nucleus. The final objective is to eliminate the historical views and images of light that still persist today and contribute to the confusion surrounding the interpretation of quantum theory. This new, radical theory of the electron has been undertaken to create a firm foundation for investigating atomic, nuclear and elementary particle phenomena. It is time to revive the progress in physics that has now been stalled for over fifty years.

1.2.5 INCLUDING HISTORY & PHILOSOPHY OF SCIENCE

As always throughout this series, two of the underlying objectives will continue to be the restoration of philosophy and the history of science to the forefront of fundamental research to regenerate their key role as engines of theoretical physics. As in each of the papers reporting on this new research programme, a broad historical perspective is deliberately introduced. This is to re-establish the context from which the new ideas are developed; these are often contrasted with the assumptions that usually drove the historical development of physics at the time. In other words, in order to understand the significance of these new ideas, it is important to recall the alternatives that were considered in the past. In particular, many of the most severe criticisms of what became the canonical evolution of physics were never answered – just ignored. This was the case in the area of studies of light in the 19th Century, when the academic mathematicians, who were investigating the differential equations found with wave phenomena, deliberately excluded supporters of the earlier corpuscular or emissionist theories.

1.3 OVERVIEW

In this overview, the contents of this paper are summarized by including a brief description of each section and the major reasons the particular material has been included. The paper ends with a 'Summary and Conclusions' that focuses on the implications of the material covered and the new results obtained, along with brief previews of future papers in this series.
It will first be useful to summarize again the objectives of this overall research programme (which were presented originally in the first paper in this series) since the objectives of the present paper can only be understood within this broader context. These objectives reflect the view that theoretical progress in physics only occurs when theory is grounded in experiment. Moreover, clear concepts that form a coherent (non-contradictory) set must be established to aid the imagination of all innovators. This is the eternal justification of philosophy that challenges all thinkers to eliminate contradiction. Unfortunately, this has not been the standard in physics in the last 60 years; rather, philosophers have been driven from the temple of physics as they kept pointing out the contradictions in the basic ideas of modern physics – this was just too embarrassing. It is good concept sets that drive the evolution of theoretical physics – not inventing mathematical equations.

1.3.1 RESEARCH PROGRAMME

Programme Objectives

Each of the papers in this series tries to follow the objectives of this programme that were set out in the first paper:

1. Restoring the roles of **metaphysics** and **visualization** to the evolution of the foundations of physics,
2. Emphasizing the value of the **history** of physics as a source of conceptual understanding and as a primary source of new ideas in this foundational science,
3. Reviving the **reputation** of many physicists whose historical contributions have been overlooked,
4. Demonstrating the value of returning to **Newton**'s metaphysical and mathematical approach to theoretical physics, emphasizing the **discrete** nature of the world both in experiments and in its representations,
5. Demonstrating that the algebra of Natural Vectors (especially in their discrete form) should be one of the most powerful mathematical techniques in the 'tool-bag' of physicists,
6. Removing the mysteries and **paradoxes** of 20th century physics, especially those arising directly from the present theories of relativity and quantum mechanics, based on the misleading (and intertwined) ideas of '**duality** of light' and 'light as an entity'.

Methodologically, this programme wishes to re-establish an approach to conducting theoretical physics that formed the successful foundation for physics since Newton but has fallen out of fashion in the 20th century. This older approach emphasized the primacy of the philosophical investigation of nature. Like all scholarly pursuits before 1900, this approach was grounded in a thorough knowledge of the historical developments of the subject not just the most recent, "modern" viewpoint. The benefits of this historical perspective were that the many contributions of earlier researchers were reviewed, re-analyzed in terms of their assumptions and the results given their due significance in the overall development of the science. The history of physics demonstrates that whenever philosophical concepts have preceded mathematics then stronger theories have resulted. Modern physics shows the profound problems that arise whenever mathematical innovation <u>precedes</u> conceptual innovation – scientists are left with equations that cannot be interpreted coherently and theoretical progress stalls for lack of intuitive and especially <u>visualizable</u> inspiration. When theoretical physics only uses mathematics, it loses its own *raison d'etre* – an **understanding** of reality: this has been the consequence of relying excessively on phenomenology.

Challenging Continuity

The present programme challenges several of the major assumptions of modern physics. Mathematically, but again related to the historical perspective, this programme focuses on the almost forgotten area of discrete mathematics, as this is closer to representing the real nature of the world. In contrast, for over 300 years physics has thoroughly explored the consequences of the "***Continuum Hypothesis***" – the metaphysical position that reality is best described in terms of DesCartes' *plenum*: the continuous inter-connectedness of the world. This has been reflected in both the extensive use of the infinitesimal **calculus** and continuous group theory. The present work starts with the discrete interaction between pairs of electrons but by explicit consideration of the many-body basis of the macroscopic world explicitly introduces the differential representation of nature as a well-defined limit process. The present programme not only challenges this central, mathematical schema but also proposes alternative, discrete conceptions of the very foundations of mechanics – velocity, mass and rotation – on the grounds that each of these concepts today is still built upon the implicit assumption of the "Continuum Hypothesis".

In his lectures on gas theory in 1895, Ludwig Boltzmann (well aware of the burgeoning atomic evidence) suggested that the differential equations of physics may represent only **average** values constructed from elements that are not themselves rigorously differentiable, particularly, if physics ultimately requires finite (rather than infinitesimal) time elements. This intuition is given explicit form in the present paper. The result of this new approach is the development of a new model of the electron (known as the **Digital Electron** model) that extends Newtonian physics both conceptually and mathematically, while preserving the metaphysical assumptions of natural philosophy (**realism**). Finally, this programme does not place **energy** on a pedestal, as it does **not** view this key concept as reflecting any fundamental entity in reality. This new theory is based only on the eternal existence of electrons (referred to here as the "**Universal Electron Theory**" or **UET**). In order to exist, these particles must interact with one another. When these interactions occur remotely (at more than atomic separations), they give rise to phenomena that have historically often been characterized as '**optical**'. This paper will demonstrate that all optical phenomena, both classical and quantum, can be re-interpreted from this purely electron interaction perspective. There is a major conceptual shift introduced simply by downgrading the metaphysical status of the concept of light from <u>entity to relationship</u>. Entities have independent existence while all relationships depend on the existence of one or more entities. This paper will explore the profound impact of this deep conceptual change.

The earlier papers in this research programme are summarized next to establish the present context.

UET1: A New Algebra for Action-at-a-Distance

The first paper [1] in this series introduced a new, non-commutative algebra, based on Hamilton's **quaternions**, which was shown to be ideally suitable for representing asynchronous action-at-a-distance. This became the basis for all subsequent analyses of the EM interaction, both for continuous charge densities (Helmholtz model) and between two discrete charges. The intrinsic anti-symmetric nature of this algebra (called '*Natural Vectors*') showed that this was the natural representation for activity involving electrons, at all separation distances and relative speeds, rather than traditional scalar algebras. One and two electron physical **invariants** arose naturally from this approach, which later became the basis for quantization.

UET2: Continuous Natural Vector Theory of EM

The continuous form of Natural Vectors was used in the second paper [2] to directly recover all the major results of classical electromagnetism (**CEM**) while avoiding all use of the field concept. It validated the retarded scalar and vector potentials approach first introduced by L. V. Lorenz, who combined Gauss's 1845 suggestion of the finite speed of interaction with Newton's action-at-a-distance model of physics into a charge-potential model of electromagnetism in 1867; it also showed the primacy and physical significance of the EM 'Lorenz' gauge. These results were based on the continuous charge-density substance model of electricity that is used today to develop the Maxwell-Heaviside Equations for CEM. This analysis also demonstrated that Helmholtz's '**fluid**' model of electricity was one of the few CEM models that can result in an explanation for the phenomenon of light. Paper II also included an extensive discussion of the role of philosophy in physics, especially the impact of **metaphysical** views on the progress in physics.

UET3: Continuous Two-Electron Theory of EM

The third paper [3] replaced spatial continuity (the classical model of continuous 'charge-density') with point electrons with finite electrical **charge** and finite **mass**. This paper proved that all continuous interaction (**force**) theories between all point particles that exhibit inertial resistance to changes in their motion are **not** consistent with asynchronous (or Gaussian) forms of action-at-a-distance or equivalently: two-particle interactions that are limited to points 'on their mutual light-cones'. This paper also introduced a many-body classical approximation ("Mesoscopic Electrodynamics") that showed that all the basic phenomena of CEM (Amperian force, induction and radiation) could be explained by a simple mechanism of conduction, which acts remotely and can be described simply in terms of weighted averages over source currents (the **vector potential**).

UET4: Classical Two-Electron Relativistic Dynamics

The fourth paper [4] investigated the hypothesis that the universal inter-electron interaction only occurs discontinuously over time. This was a return to Newton's original idea of fixed **impulses** and gave a new mechanical explanation for Planck's 1907 Proposal for the formulae of relativistic point-particle mechanics while preserving each electron's invariant inertial mass at all speeds. This analysis showed that two-electron interactions must be defined in terms of symmetric, two-time variables rather than the traditional single ('God-like') time. Historically, Einstein founded his special theory of **relativity** on the invariant speed of light derived from Maxwell's EM theory. This foundational theory of modern physics was critically reviewed in paper IV, where the so-called relativistic effects were shown to be the direct result of the varying asynchronous **delays** occurring between the emission and absorption of the EM interaction between two remote electrons.

UET5: Discrete Electron Relativistic Dynamics

The fifth paper [5] introduced a **new form** for the asynchronous interaction between two electrons that diminishes linearly with temporal separation to a finite, fixed value. The discrete electron interaction was universalized by proposing a simple form for quantizing the dynamical and kinematical **activity** between interacting electrons. This proposal leads to a dynamic exchange of quantized **action** ($h/2$) replacing Coulomb's continuous and instantaneous 'law' of electrostatics. This replaces Planck's arbitrary (mathematical) quantum of action 'rule' (which was first injected into radiation theory and then later into atomic physics) and has been thought to provide a universal **physical** explanation for all atomic phenomena throughout the 20th Century when its introduction was purely mathematical. This model also demonstrated that the temporally symmetric fixed exchange of momentum over finite distances and times (Gaussian action-at-a-distance) between electrons provides a simple mechanical explanation for the mysterious two-valued quantum phenomenon of electron '**spin**'. A new mathematical representation of this two-particle EM interaction using *Discrete Natural Vectors* provided further insights into Dirac's 1928 Equation of the Relativistic Electron, including the real nature of the **positive electron**. Both forms of the electron were shown to execute a four-step, transverse, cyclic trajectory across space (but twisting in opposite directions). Since this 'new' motion is sub-microscopic, this may be viewed as the 'hidden degree of freedom' that characterizes this mysterious behavior of the electron.

1.3.2 CLASSICAL OPTICAL PHENOMENA

Section II summarizes the experimental phenomena that have formed the foundation of optical studies. A clear separation is made between the empirical evidence which forms the unimpeachable basis of physics and the theoretical explanations which are always more problematic. Unfortunately, optics is almost always presented today as an integral blend of theory and experiment, giving the deliberate impression to new students of physics that the theoretical basis (usually the wave theory) is as solid as the experimental evidence. Since the wave theory (summarized in section III) is being challenged in this paper it is important to identify those physical phenomena which must be re-interpreted by any new theory that is not simply a disguised presentation of the mathematics of waves. The actual optical phenomena are presented here as objective facts without any accompanying explanations. The new interpretations of the full range of optical experiments based on the new theory developed here are presented in section VII.

Classical optics has always focused on experimental situations that involve intense light traversing bulk matter. Quantum optics only appeared when very faint light could be observed to interact with a limited number of atoms. It is the need to reconcile these two contradictory viewpoints that has left physics in a 'metaphysical mess'.

1.3.3 NATURE OF LIGHT – CLASSICAL THEORIES

1.3.3.1 The 100 Year (Metaphysical) War

The **æther** EM debate of the 1900s mirrored the earlier metaphysical battle over the true nature of light that was conducted in the 1800s in the French Academy of Sciences between the followers of Newton (the 'emissionists', who viewed light as rays) like Biot and Malus and the new promoters of Huygens' wave theory (the 'ætherists') like Fresnel and Arago. This fundamental disagreement on the nature of light was extended into a theory-war to explain the nature of electricity by 1860.

1.3.3.2 Mathematics 'explains' Light

For the last 300 years, physicists have successfully abstracted out of the complexity of atomic reality a series of simplified models that can all be represented mathematically and solved in very simple situations. Unfortunately, in modern times, when theoretical physicists even think about the philosophical meaning of the symbols they far too often fall into the error of **reification** – a logical hole, first fallen into by Plato, who was a firm believer in the primacy of mathematics ("forms"). This subsection is introduced to illustrate how confused are many of the ideas linking Maxwell's EM theory to classical explanations of light, especially the several myths that have grown up around the EM experiments of Heinrich **Hertz**.

1.3.3.3 Energy

Section 3.3 is introduced to **critique** the late-19th Century idea that even if light were neither a wave nor a particle, it could still be viewed as 'identifiable energy moving across space'. This will be shown to be a philosophically empty concept that tried to fill in for the disappearance of the æther as the physical medium of Maxwell's EM theory: thinking about **energy** concepts is one of the most confused areas in modern physics. This section also reviews several other theories of EM that have contributed to the present universal electron theory; most of these are either long forgotten or little known.

1.3.3.4 Traditional Light Models

This sub-section summarizes the major problems with the classical models of light, with the emphasis on the **wave** model that is viewed as our best explanation to date for all the non-quantum optical phenomena. This section also severely criticizes the use of **field** theory (as exemplified by Maxwell's theory of EM) as a suitable basis for optical phenomena.

1.3.3.5 The Metaphysics of Light

Section 3.5 returns to **Aristotle** by deliberately including a discussion on the nature of **reality** and the real existents that are found therein (**ontology**). Until the 20th Century this was always the foundation of theoretical physics – it is intellectually dishonest to presume that physics can avoid discussing its own foundational assumptions. Modern physics also fails to address the key issue of **epistemology**: how we know what we know about nature. This failure has led directly to the confusion that surrounds the whole subject of our knowledge of atomic scale phenomena, that is to say: quantum mechanics.

1.3.4 QUANTUM OPTICS & PHOTON THEORY

The fourth section is included to emphasize the **discrete** phenomena that have led to the idea of the **particle** nature of light. Section IV summarizes the key experiments that introduced the radical idea that light has discrete properties as well as wave properties. Once again, the experimental facts are kept separate from the theoretical explanations and the related criticisms.

1.3.4.1 Planck's Quantum

The first sub-section acknowledges the key role that Max **Planck** played as the reluctant father of modern quantum theory. The emphasis here is once again on the mass confusion of beginning with phenomenology; in particular the artificial introduction of Planck's energy-frequency relationship to 'solve' the blackbody problem. This brought the discrete quantum of action to the notice of theoretical physics without having to use any physical concepts to justify this revolutionary step.

1.3.4.2 Einstein's Photon

The second section in the area of quantum optics focuses on Hertz's discovery of the photoelectric effect and Einstein's radical explanation of this unexpected discovery using Planck's quantum equation and his concept of the light **quantum**.

1.3.4.3 Einstein's Photon-Gas

Section 4.3 reverses history a little and discusses how Einstein again used the Planck energy-frequency equation as a key component in his model of blackbody radiation in a cavity to recreate Planck's radiation distribution formula. Again, by making a mathematical proposition, based purely on mathematical analogy, Einstein was able to create a formula that agrees with experimental results (phenomenology) but the complete lack of any physical justification leads to massive, conceptual confusion. This methodological failure is illustrated here by focusing on the eleven-year delay in adding the property of quantized momentum as a fundamental component of the idea of the photon, introduced first only as quantized energy.

1.3.4.4 Einstein's Laser

This part summarizes Einstein's proposal for the stimulated emission of radiation as an alternative approach to recreating once again Planck's radiation distribution formula. Again, lack of physical insights led to an almost forty-year delay in extending this theory to a practical technology, with engineers **ignoring** theoreticians' insistence on its 'impossibility'.

1.3.4.5 Photon Problems

This sub-section discusses the basic problems with both Planck's energy-frequency equation and Einstein's photon concept. Several of these criticisms repeated here have a long history but have never been answered satisfactorily – they just got conveniently forgotten.

1.3.5 LIGHT & QUANTUM ELECTRODYNAMICS

Section V summarizes the physical and mathematical models that have been used in the 20th Century to describe 'light'. The present theory situates the 'paradox' of light as "wave or particle" in the pre-Twentieth Century predilection for falling back on **phenomenology** – the invention of equations relating measurable parameters without first developing a conceptual schema to understand the entities involved. Since the phenomenon of light is so fundamental, it has resisted all mechanical models and modern physics has described the effects purely in mathematical terms. When the mathematical ideas of modern quantum mechanics were merged with the mathematics of classical fields the result became known as quantum field theory. Any glance at a modern text on Quantum Optics would suggest that it was a book of applied advanced mathematics, not physics.

1.3.5.1 Quantum Electrodynamics (QED)

This section summarizes the transformation from quantum mechanics (QM) to quantum field theory (QFT) because this theory is now regarded as "*the best theory in physics*" – a view that is **not** shared here. Ironically, modern physics began when the ancient cosmology of Ptolemy was rejected by Galileo and Copernicus even though the Ptolemaic experts could predict the appearance of planets (and eclipses) with much greater accuracy than the Copernican model. Galileo was prepared to be burned to justify his view that the Earth actually did revolve around the Sun. Now, contemporary physicists are excessively proud of the accuracy of the QFT calculations of the tiniest changes in the magnetic behavior of electrons even though their mathematics is built on spurious infinities and **no** real interpretations of their mathematics are available.

1.3.5.2 Feynman's Electrodynamics

Even particles eventually were described in terms of quantum **fields** so that the final version emerged in a form now known as quantum electrodynamics (QED). In contrast, the present theory is able to resolve these conceptual problems simply in terms of **electrons as particles**. The heart of this section is a summary and critique of Feynman's version of QFT usually referred to as QED as this is now widely regarded "*the best theory we have*"; it now is taught to all physics post-graduates. This section is included to demonstrate the points of difference and similarity between Feynman's approach and the present theory; not the least of which is Feynman's revolutionary approach to handling the concept of time. The present programme reverts to Feynman's original ideas: electrons do **not** interact with themselves and there is no such existent as the EM field. Although Feynman offered a very intuitively appealing mathematical scheme ('***Feynman Diagrams***'), he could not improve on Newton's "*explanation*" of **fits** of reflection and refraction at a boundary; he just gave it a **probabilistic** coating.

1.3.5.3 Problems with the QED Model

This sub-section describes some of the deep problems with the whole QFT approach to remote EM interactions ('radiation'); this is important because many of these problems recur in all QFT theories used in today's theoretical models, although they are rarely acknowledged. This section tries to retrieve some physics of value from Feynman's approach to QED but strongly **rejects** the idea that '**virtual**' particles have any existence or utility.

1.3.6 LIGHT AS REMOTE ELECTRON INTERACTIONS

Section VI introduces the multi-electron part of the UET. However, before describing the conceptual and mathematical aspects of this part of UET, this section offers a brief digression into the pernicious effects of the role of **phenomenology**. This is included because it has largely been forgotten that it was the failure of the two mainstreams of 19th century EM studies (in both Britain and Germany) to provide any satisfactory physical explanations of the fact of remote EM **induction** (more widely referred to as '**radiation**') that led to the universal acceptance of a purely mathematical exposition (Maxwell's Equations). Both Maxwell and Helmholtz viewed electric charge as a **condition in the æther**, not as a distinct entity like the electron. This major failure set the scene for subsequent, purely mathematical 'explanations' for most of 20th Century theoretical physics. These two 19th Century EM theories, along with that of their principal rival (Weber's electrodynamics based on point-to-point EM force models) are summarized in a table to illustrate the intellectual **roots** of the present UET.

1.3.6.1 Discrete Electron Interactions

The important idea here is that 'light' is **not** a carrier of the interaction between two interacting electrons – this would require the introduction of a new entity or 'medium of existence' ("force density" is a mathematical, not ontological concept). It is the interaction itself (i.e. the change in the relationship between the two interacting electrons) that is the focus of these investigations. It is the characteristics of this interaction that actually defines the nature of the electron; these have been introduced gradually with the publication of this research programme. They are reviewed again here. Physically, the EM interaction manifests itself as a pair of co-ordinated impulses that are experienced by each electron. These impulses alter the momentum of each electron at the moments of interaction ('the interaction event'). These two impulses are integral components of this single relationship: the electron interaction occurring between one pair of electrons at unique times for each electron. When a single interaction occurs between two electrons the identity of each electron has already been established – this is the heart of the present **selection** mechanism and contrasts completely with the anonymous, haphazard '**broadcast**' mechanism of QFT.

The repeated **set** of interactions between one pair of remote electrons is now viewed here as the reality lying behind Einstein's mysterious concept of the 'quantum of light' or ***photon***. This has the ray-like effects of a particle while exhibiting periodic variations that are usually associated with the mathematical model of a continuously varying wave.

1.3.6.2 Two Electron Remote Interactions

The first version of this EM theory proposed that the EM impulse operated purely longitudinally (along the line of centers), quantizing this interaction forced a reduction in the magnitude of this impulse that varied with their absolute separation. This sub-section extends the earlier longitudinal impulse model to include transverse interactions. It is shown here that if the interaction is to remain quantized at all distances then there must be a small transverse component that becomes dominant at 'far' separations (exceeding 1 mm). This not only explained '**magnetic**' effects but it was found to be the necessary mechanism for **radiation**. Transverse impulses exchange one quantum of speed b defined as c / N_0, where N_0 is the maximum number of interactions two electrons may participate in consecutively.

The majority of this chapter (beginning at §6.2.5) is dedicated to finding an analytic solution to the problem of two-electron **scattering** that respects the full, asynchronous interaction between them. This is a problem that has resisted all earlier attempts, using either Maxwell's theory or quantized versions (QED). The principal simplifying assumption of field theory (everything reduced to one location and one time) was too extensive to uncover the subtle correlations across space and time. In contrast to the standard assumptions, the electrons in this theory follow real trajectories and these are investigated here. The simpler 2D model is analyzed extensively and then extrapolated to a full 3D solution.

1.3.6.3 Two Electron Remote Interactions

The main part of this section extends the two-electron interaction, which lies at the heart of this new theory, into a statistical approximation suitable for describing macroscopic phenomena. This dynamical interaction is contrasted with Coulomb's **electrostatic** model, which is seen as a macroscopic approximation, statistically averaged over an extended time span – one that is not suitable for the foundation of EM.

The second half here (section 6.3) explores the statistical approximation that is introduced to describe the extreme complexity of the real world with its myriads of interactions between vast numbers of electrons found in macroscopic objects. The key here is to exploit the idea of **saturation** – only pairs of electrons interact at any one time, reducing the quadratic complexity in the unsaturated situation to a linear problem. This requires **selection** rules to be identified that define the actual 'partnerships' between electrons from all possible interaction pairings. This perspective introduces the key function of **information**: Each time an electron participates in an interaction it needs to know *the when and the where* of its partner in this transaction making this is an inherently **non-local** theory. Classical theory avoids this problem by adopting a 'broadcast' model of the interaction: a disturbance occurs somewhere in the pond and a spherical ripple just progresses from there outward eventually across all of space changing everything it encounters. The present theory exploits the four-click digital electron model, using information exchange both forwards and backwards across time, to decide which other electron will minimize total action in the next interaction cycle. It is this selection mechanism that defines the 'light path' and the fact that quantum mechanics exhibits an apparent statistical behavior. Selection is described in two phases: a query phase (anyone interested?) and a reply phase (I am!). The query phase is assumed to be *isotropic* in every direction but every actual interaction (a selected reply) is always **ray-like**. A simple set of Selection-Rules are proposed that are subsequently used to explain the wavelike characteristics of light; examples are pictured illustrating the prototypical three-electron rules. Even though the information exchanges are also propagated at light-speed, the two-way mechanism across time means that the whole universe can be scanned in one cycle – this provides the non-locality **trans-luminal** mechanism that underlies the Aspect experiments. It is also suggested that this mechanism is critical in nuclear physics.

1.3.6.4 Key Role of the Source

This section restores the source of 'light' to center stage; no longer will the analysis begin with a mysteriously generated light wave or photon interacting with electrons; there must be an explicit source if the target electron is going to interact with other electrons. A **generic** source mechanism is first developed that can be applied to all optical situations. This model is elaborated to include the famous Bohr frequency rule. It is also extended to include the constancy of frequency. Atomic radiation is obviously the first example of the generic source mechanism, which is shown to cover blackbody radiation. An EM antenna is also included as a generic source to explain the physics of Hertzian radiation using the earlier mesoscopic model of conduction, developed in paper III.

1.3.7 NEW EXPLANATIONS OF OPTICAL EFFECTS

Section VII returns to the experimental phenomena that were introduced in section II and were explained by classical optical theories in section III. Here these experiments are re-interpreted in terms of the theory developed in section V. This section is the **crux** of this paper. The first part (7.1) zeros in on Maxwell's (and Lorenz's) principal innovation: the electro-kinetic momentum (or vector potential, using modern terminology). The next part (7.2) shows how action-at-a-distance is a natural explanation for the 'path' of light. Atomic scattering is introduced next (7.3) to model the many-body effects of the many EM interactions needed when two media (including the vacuum) are involved. This approach is extended next (7.4) to show how Fresnel's mathematical approach to **diffraction** can be interpreted in terms of action-at-a-distance to explain optical **interference**. This approach is continued with discrete explanations of polarization and aberration, while this section ends with an extensive blackbody radiation (7.7) and a purely electron-electron explanation to replace the 'photon' concept (7.8).

1.3.8 SUMMARY & CONCLUSIONS

The final section deliberately summarizes the major points in this large paper for those readers whose time is limited. It was the mistaken belief that Maxwell's **source-less** equations described microscopic reality and his failure to recognize that permanent magnets were electrons in motion that led Einstein to create the special theory of relativity. The creation of a better theory of electron dynamics will therefore be strongly **resisted** by most physicists. As Max Planck wrote in his short book of essays: "*A scientific innovation rarely makes its way by gradually winning over and converting its opponents. What does happen is that its opponents gradually die out and that the growing generation is familiarized with the idea from the beginning*." [6]

This paper has again returned to its primary focus – the **electromagnetic interaction**, particularly as Maxwell's ætherist theory of EM is widely thought to provide a comprehensive explanation of the traditional experiments associated with the phenomenon known as 'light'. The inclusion of much **historical** material has been deliberate here, even though this is no longer the fashion in contemporary theoretical physics papers, because the new EM theory presented here traces its own roots back to rival 19th Century EM theories. Similarly, a **philosophical** slant has been deliberately included because metaphysics always underlies (although usually implicitly) all fundamental theories in physics – it is this extra viewpoint that distinguishes theoretical physics from applied mathematics, where "*anything goes*". These historical and philosophical dimensions are particularly important when examining the fundamentals of 'light' as theoretical innovations in this area have provided the justification for the foundations of the two major pillars of 20th Century physics: SRT and QM. Since most scientists are very conservative, it was necessary to demonstrate that there are alternative explanations to the accepted views of 'light' so that new approaches to these other areas can be investigated with confidence. These will be the areas reported on in subsequent papers in this research programme.

2. CLASSICAL LIGHT PHENOMENA

This section will set the stage for the rest of the paper; in particular, it will review the historical context of the two major ideas that are the focus here, namely: the concept of light-waves and the earlier notion of corpuscles of light. As described in the introduction, outstanding historical criticisms of the orthodox ontological theories will be discussed and several new problems will be introduced. Later sections will re-examine and re-interpret these two key concepts as explanations for the nature of light. Students of physics (and their teachers) are today almost completely unaware of the assumptions underlying their present theories or the major conceptual weaknesses hidden within them, since the history of science has been relegated to a small group of specialists. It is important to realize that only one of the possible pathways through the evolution of science has usually been developed. Sociologists of science have shown that this singular evolution is more a reflection of **academic politics** than it is a '*Discovery of the Truth*'. The 'pressure to publish' has increasingly compelled researchers to only focus on the latest activities – adding another 'brick in the wall' may not be the best use of one's time when the castle that is being constructed is floating off into the clouds. Although the ideas of optics, especially the metaphysical assumptions concerning the nature of light, underlie much of modern physics, they are rarely discussed in the one semester course that is all that most physicists receive today since **optics** is now seen as "old science".

2.1 THE IMPORTANCE OF LIGHT

Sir Edmund Whittaker, in his magisterial history of electrical studies [7], quotes a powerful (but now largely ignored) aphorism of natural philosopher Roger Coates, who in 1713 stated that: "only observable events should be part of physics." Rather than introducing unobservable waves or photons, this new theory is grounded on the observable motion of electrons.

Both Planck and Einstein built their models of light on Maxwell's EM theory. Planck tried to preserve Maxwell's field theory in his radiation model by locating the quantum of action in its interaction with matter, not in the radiation field itself; i.e. in the processes of emission and absorption. This still presented Planck with unresolvable problems: there are no discrete elements of action in Maxwell's EM theory. Indeed, in 1899, only one year before his revolutionary theory was published, Planck himself had explicitly pointed out that Maxwell's Equations are constructed on the assumption of continuous action, where the space and time co-ordinates enter as differentials, whereas in action-at-a-distance theories, they always appear as finite intervals. Even Einstein suspected that Maxwell's Equations might have to be revised before the conceptual and mathematical dualism of light and matter could be resolved; Maxwell's EM theory is **not** the basis of the present theory.

2.1.1 A HISTORY OF LIGHT

An Ancient History

Vision is the most important sense in all higher animals, including Man (over 70% of our sensors are in our eyes). This allows each seeing creature to become aware of even small changes in its wide surroundings so that action can be taken. Philosophers have pondered this experience from earliest times. All humans (except the blind) can experience the world in color (red through blue) and can easily show that when three objects are viewed in a line their edges can be seen. These effects have been interpreted widely to imply that light possesses the properties of color and movement in a straight-line. Pythagoras believed that visible objects emitted particles that bombarded the eye, just like stones thrown by an enemy. Aristotle took the contrarian view that light was not something in motion but only that something was present.

The Classical Era of Optics

The fundamental disagreement on the **metaphysical** nature of light began back in 1704 when **Newton** proposed that light consisted of corpuscles emitted from the source and then moving in straight-lines ('**rays**') to the receiver. This was an explicit rebuttal of **Huygens**' 1690 proposal of optical vibrations spreading across **all** of space in a universal **æther**. The followers of Newton's optical theory (known as 'emissionists') viewed a beam of light as a finite collection of individual rays that (in theory) could be counted directly, representing the intensity of the beam. Each ray was viewed as possessing an unchanging, intrinsic asymmetry so that polarization was explained as an unbalanced collection of these rays. Newton's own greatest optical triumph was his demonstration that ordinary (white) light was a mix of light of all colors or frequencies. Interest in optics was sadly much diminished in the 18th Century but was vigorously revived around 1800, in both France and England. Malus, Fresnel and Young made major experimental and theoretical contributions and are discussed in section III.

Modern Times

James Clerk **Maxwell** is today widely viewed as the originator of the modern theory of light. Actually, Maxwell provided a new mathematical formulation of the wave theory of light by proposing that it was the result of EM vibrations in the æther. This theory is widely thought to have been confirmed after Heinrich Hertz's generation and detection of EM waves in 1889. The second paper in this series [2] critically reviewed Maxwell's EM theory and the rival EM theories that were developed in the second half of the 19th Century that are now largely forgotten.

Maxwell had proposed a real experiment to measure the difference in the travel times of a light beam split in two so that one half had its speed modified by that of the Earth traveling through the æther while the other half was unaffected by traveling at 90º to the first. Recombination should show interference effects and an accurate measurement would then show the earth's speed through the æther. Eventually this experiment was carried out to sufficient accuracy by Albert Michelson and Edward Morley in 1887. This was one of the most important experiments in the history of physics as its truly surprising null result shattered the near-universal belief in the existence of the æther as the actual basis for light. There were several desperate attempts to preserve Maxwell's EM theory, which had become one of the principal foundations of modern physics; these included æther-dragging, high-speed object contraction and finally Einstein's special theory of relativity. Scientists are reluctant to give up on a theory (belief set) once it has gained wide acceptance. Digging up foundations is not encouraged. Scientific heretics may no longer be burned at the stake but clever people know where the wind is blowing.

In 1887, Heinrich **Hertz** discovered that when ultraviolet light was shone onto metallic electrodes the voltage required for induced sparking to take place was lowered: this became known as the *photoelectric effect*. The final step in "the mystery that is light" was found when very low-intensity light was directed at a screen with two close parallel slits: individual spots of light are found on the receiving surface, which (with repetition) gradually build up to match the interference results found when high-intensity light hits the screen. These two sets of experiments are now thought to demonstrate that light itself has the 'complementary' properties of particles, as well as the classical properties of waves, as shown by **interference** effects.

In 1953, Charles **Townes** produced the first microwave amplifier but this was incapable of continuous output. At the same time, in the Soviet Union, N. Basov and A. Prokhorov were independently working on a microwave oscillator that produced continuous output by using more than two energy levels. In 1958, Schawlow and Townes published their own theoretical calculations [8] while Bell Labs filed a patent application for their proposed optical maser. Simultaneously, at Columbia University, doctoral candidate Gordon Gould was working on the energy levels of excited thallium. He published his own results in 1959, along with his new acronym: the ***laser*** [9]. In 1964, Townes, Basov and Prokhorov shared the Nobel Prize for Physics "*for fundamental work in the field of quantum electronics, which has led to the construction of oscillators and amplifiers based on the maser–laser principle*". Astonishingly, Townes has written [10] that several eminent physicists (including Bohr and von Neumann) **denied** that such devices could ever be constructed, claiming that this would violate Heisenberg's Uncertainty Principle – an example of the confusion surrounding the interpretation of this central tenet of quantum mechanics (and the arrogance of theorists over the reality created by engineers!).

2.1.2 PHYSICAL PROPERTIES OF LIGHT

Frequency

The two competing models of 'vibrating' particles and vibrating media (waves) share the universal idea of frequency but only the wave model requires the concept of **wavelength**. As a result, this paper will only focus on frequency concepts when discussing the key characteristic of optical phenomena. Similarly, both particles and wave pulses can be said to travel with a measurable velocity – this concept will also be retained, in a modified form, for most of this paper when discussing light. In particular, '**light-speed**' will be used to define the commensurate space and time differences that constrain when two electrons may exchange momentum via the asynchronous EM interaction – a constraint referred to as "on the light-cone" and discussed extensively throughout this research programme.

Color

Humans can detect objects, which emit or reflect light in the red to blue color range. These involve frequency variations in the external environment of about 4 to 8 x 10^{14} per second or processes that only last between 1 to 2 x 10^{-15} seconds: these are very brief events on the normal human scale of experience. The addition of modern technology enables human to conduct temporal measurements in this range down to a further discrimination of about 1 part in ten million. It is the view of this theory that the finest duration of time is quantized at about 10^{-24} seconds, a value referred to here as the *chronon*.

2.1.3 GEOMETRIC OPTICS

Rays

The impression that light travels in straight lines was well known to Ancient Greek scholars so the transition from optics to **geometry** seemed obvious with the ray of light traveling in a homogenous medium mapping to a geometric line. Light was simply assumed to move in a straight line until it reached the boundary with another medium [11]. This view was adopted explicitly in the mathematical model known as ***geometric optics***. This perspective will be briefly reviewed here as it is the prototypical example of how a mathematical representation becomes **reified** – a very natural leap for mathematicians who usually think their representations are not only unique but that all their mathematical components map one-to-one with all the corresponding components of **reality**. It will be seen that this logical fallacy underlies all the fierce philosophical debates about the real nature of light and usually occurs when new theories are **first** proposed as sets of mathematical equations rather than imaginative concepts that are subsequently summarized with mathematics.

The distinction between geometrical optics and reality appears as soon as attempts are made to isolate a single ray of light. When the smallest source of light ("point source") is placed behind a screen with a small hole in it and a target (observation) screen then placed along the same axis then a bright area, resembling the hole, appears on the target screen. Straight lines may then be drawn between the edge of the first hole and its image on the target and interpreted as *light rays*. If the blocking hole is made smaller the image shrinks accordingly but experiments show that at a certain size (varying with the color) to **spread** over a considerable area of the target screen. This failure is called **diffraction** and is usually explained by assuming that light behaves as a wave, when it is discussed in terms of ***physical optics***. We will show that this is actually not a physical explanation but an application of the mathematics of waves to describe these phenomena.

Fermat's Principle defines the Optical Path

Fermat's (optical) Principle of Least Time is often stated as light takes a path through an optical system that minimizes its total travel time. But a more general (mathematical) statement is: "The path taken by a light ray going from one point to another through any set of media is such as to render its optical path equal, in first approximation, to other paths closely adjacent to the actual path" i.e. a stationary solution.

Optical Aberration

Optical aberration is the fact that real optical systems do not exactly match our theoretical predictions. The best predictive scheme is called ***Gaussian Optics*** and traces geometric rays close (within 10°) to the optical axis of the system. It occurs because light originating at different points in a planar source do not replicate exactly on a single observational plane after transmission through the system; it is not a problem with the equipment (lenses or mirrors) or experiment but a failure of the mathematics of geometric optics to reflect reality. Aberrations occur even with monochromatic light and are due to how light is reflected or refracted by the geometries of a lens or mirror.

Spherical aberration occurs when rays emerging from a common source point hit different parts of a spherical surface and emerge in different directions relative to the optical axis, resulting in a blurring in any target (observation) plane. Even when the source point is very far from the spherical surface (i.e. the incident rays are parallel) their impact points vary along the spherical surface and still hit different points (and times) on the observational plane.

Since 'mixed' light of different frequencies, f is refracted differently by a lens then dispersion occurs when chromatic light is generated at the source and is "transmitted" through the optical system. Dispersion occurs as the phase velocity $\mathbf{V}$ of the travelling waves depends inversely on the refractive index n of the medium and this varies with frequency so: $\mathbf{V} = c / n[f]$.

2.2 EMISSION, TRANSMISSION & REFLECTION

Light as a Process

Historically optical phenomena were explained in terms of ***paths*** through empty space or through suitable media. Until the confirmation of the atomic hypothesis around 1900, this was the only way that this important area could be investigated. It seemed obvious to everyone that light must be some basic type of existent that moved from shining objects to our eyes. The present examination does not follow this view but treats optical phenomena as physical processes, examining how this real complexity can be analyzed in terms of a series of interactions between emission, re-emission and eventual absorption. An atomic model of the emission and absorption processes will be presented in a later paper (VII).

2.2.1 LIGHT EMISSION

Point Sources

The one common factor that remained throughout the first 300 years of optical science was the use of 'point' sources – an assumption introduced for simplicity that held a very powerful **clue**. The use of astronomical objects, such as stars, means that the actual sources of these remote emissions contain gigantic numbers of emitting atoms; the 'point' source is only an optical illusion of narrowness in the angular field when viewed from the distant receiver. The ultimate source of every 'light' interaction is always a single electron and, in the present theory, this **is** always viewed as an actual point in space.

2.2.2 TRANSMISSION ACROSS SPACE

Rays

The impression that light travels in straight lines was well known to Ancient Greek scholars so the transition from optics to geometry seemed obvious with the ray of light traveling in a homogenous medium mapping to a geometric line. Light was simply assumed to move in a straight line until it reached the boundary with another medium [11]. This view was adopted explicitly in the mathematical area known as *geometric optics* (see §2.1.3).

Shadows

It is the apparent sharp edge of shadows that persuades most people that light travels in straight lines. It took over one hundred years for scientists studying diffraction to discover that this intuition about shadows was only an approximation. Indeed, it was this 'bending' effect that persuaded Newton that light could not be waves as he was aware that ocean waves would bend around obstacles and could not believe that light would oscillate at such extremely high frequencies so as to bend around edges. Newton's assumption illustrates the human arrogance that nature must be constructed around humans.

2.2.3 TRANSMISSION THROUGH MATTER

Luminous Sources

Luminous objects are defined as those that **emit** (or originate) their own light (direct), while non-luminous objects can only be viewed by reflecting light from another originating luminous source (indirect).

Transparency, Translucency & Opacity

Objects viewed by either direct or indirect light can be seen **through** many types of material media, including gases, liquids and solids: sometimes clearly (transparent media) or indistinctly (translucent); if the material completely blocks all visible light it is called opaque. These properties (for a given medium) are sensitive to the frequency of the light involved.

Bending the Light

Many optical effects are viewed as the result of light appearing to change its direction at the boundary between two different media (including empty space) – this will be referred to as 'bending'. This term will continue to be used for its direct visual imagery in spite of the obvious implication of an entity traveling on its independent journey through space. Again, the degree of 'bending' turns out to be a function of the frequency of the light involved.

2.2.4 THE SPEED OF LIGHT

A Quick History

The Greek philosopher Empedocles claimed that light was some kind of **substance in motion** – a view formalized by Euclid and Ptolemy who added the idea that this motion was infinitely fast. So, until the 17th Century, no one thought of light as having a finite speed, everyone agreed that it moved instantaneously between its source and the observer, "so that God could see the whole universe at a glance". Galileo was the first to challenge this opinion in 1667 using lamps and a water clock; he concluded that it was "at least ten times faster than sound". In 1675, Ole **Roemer** (1644-1710) decided that light must travel at least 200,000 kilometers of space in every second. This conclusion was based on his measurements of the eclipses of Jupiter's moon Io, which was assumed to rotate around Jupiter at a constant rate but this rate was observed to vary with the calculated separation between Jupiter and Earth; the temporal variability arising from the different distances that the observed light had to travel. The next great improvement came in 1728, when James Bradley (1693-1762) used stellar aberration and the speed of the Earth's solar orbit to calculate the speed of light in vacuum to be about 301,000 km per second. This very accurate result (within 0.4%) was improved upon around 1849 by Hippolyte **Fizeau** (1819-1896), who shone a light between the teeth of a rapidly rotating wheel while a distant mirror reflected the beam back between the teeth, a fraction of a second later. Fizeau was able to measure the speed of light in both air and in water. This finally showed that (contra DesCartes and confirming Fermat's guess) light moves more slowly in a dense medium, like water, than in a more rarified medium such as air. It was proposed that light would achieve its maximum speed in the absence of all matter, i.e. in a vacuum, where the speed was estimated to be 313,300 km/s. Finally, in 1862, using a technique based on Fizeau's design but extended to using a remote spinning mirror, Leon Foucault (1819-1868) achieved an accuracy of one part in a million with his determination of a value of 299,796 km/s.

The most accurate experiments to date have determined 'light-speed' to be 299,792,458 meters per second (denoted by c), often approximated to 300,000 km/s or about 186,000 miles per second or 700 million miles an hour. This is very fast on the human scale; for example, the distance from the Earth to the Moon is about 240,000 miles so that a radar beam would take about 2½ seconds to go from the Earth to the Moon and back. Over most direct human distances, our nervous systems appear to view optical effects **simultaneously** 'confirming' the ancient intuition about the speed of light.

2.2.5 REFLECTION

Reflection has always been viewed as the bending of light <u>back</u> into the incident medium after meeting the boundary of the second medium, which may or may not be transparent. It is found that the phase of the reflected light is opposite to that of the incident beam; in other words, there is an instantaneous <u>180 degrees shift in phase</u> at the point of reflection [12]. This is the oldest experimental observation about light, codified as the Law of Reflection: "The reflected ray lies in the plane of incidence and the angle of reflection (to the normal) is equal to the angle of incidence." It is found experimentally that, at normal incidence, **about 4%** of the intensity of a beam of unpolarized visible light is reflected from a single glass surface.

Conservation of Frequency

When monochromatic light passes through any fixed optical system there is always one property that is always conserved: ***frequency***. The original frequency is only found to vary if the complete optical path contains a moving mirror or if there is a difference in the motion of the emitter and the observer (or 'target' electron). This invariance is a most important **clue**.

2.3 REFRACTION & DIFFRACTION

2.3.1 REFRACTION

Refraction occurs when light, incident on the boundary of a second (transparent) medium, appears to bend <u>into</u> the second medium, with a certain fraction of the light passing into the second medium: refraction is the complement of reflection. The Law of refraction, often called Snell's Law (after Dutch physicist Willebrord Snell in 1621) states: "The refracted ray lies in the plane of incidence and the sine of the angle of refraction ϕ' bears a constant ratio to the sine of the angle of incidence ϕ."

$\sin\phi' = K \sin\phi$ The constant K is the ratio of the refractive indices n of the two media; $K = n / n'$

So, an alternative formulation is: $$n' \sin\phi' = n \sin\phi$$

Refractive Index

Experiments have confirmed that light propagates through transparent materials, such as glass, water or air, at a speed v, which is always less than its speed in vacuum c. The fixed ratio between c and v is called the **refractive index** n of the material, where $n = c / v$. For example, the refractive index of glass, at optical frequencies, is close to 1.5 implying that light in glass travels at about 200,000 km/s while the refractive index in air is about 1.0003, so the speed of light in air is very close to c. The velocity in a medium can vary with frequency f so this will make the refractive index frequency dependent, i.e. $n[f]$. For example, in the case of clear water, the velocity of yellow light (e.g. from a sodium source) is almost ¾ c so that the refractive index for water, with respect to yellow light, is nearly 4/3; this is usually at zero degrees centigrade, as the temperature of the material medium also affects the refractive index.

Phase & Group Velocities

The speed that the peaks of an **infinite** sine wave of frequency f propagate through a homogenous medium is known as its **phase velocity**, which may vary with frequency, $v[f]$. In one complete period $T = 1/f$ each point on the sine wave moves a distance λ, known as the **wavelength**. All such waves then satisfy the velocity equation: $v[f] = \lambda / T = f \lambda$. When a short pulse propagates through a homogenous medium, it may be considered as a collection of finite sine waves with a range of frequencies. The speed of this **pulse** through the medium is known as the **group velocity** $u_g[f]$ – it depends on the distribution of these frequencies. Any medium that propagates a pulse with different group velocities is called *dispersive*.

Each solution of the wave equation may be combined into a composite solution (Young's principle of superposition). For a one-dimensional medium (like a long string) the transverse *displacement* ϕ from the equilibrium position at a point x from the arbitrary origin varies over each period between two maxima ± A, where A is known as the **amplitude**. At time t the displacement is given by the sine wave solution:

$$\phi[t ; x] = A \sin [2\pi (t / T - x / \lambda)] = A \sin [\omega t - k x] = A \sin k [v t - x] \quad \text{where} \quad \omega \equiv 2\pi f \quad \text{and} \quad k \equiv 2\pi / \lambda$$

Three-dimensional waves expanding outwards everywhere from the origin have a solution: $\phi[t ; r] = A \sin [\omega t - k r] / r$

The group-velocity is always defined by the relationship: $u_g[f] \equiv d/dk\, [v k] = 2\pi\, d/dk\, [f[k]]$

The phenomenon of 'slow light' occurs when there is a dramatic reduction in group-velocity of light but no change in the phase velocity. In a **vacuum**, the phase velocity of light is <u>independent</u> of frequency, i.e. $v[f] = c$ or $c = f \lambda = u_g[f]$.

It should be noted that <u>all</u> earth-bound methods actually measure the group-velocity of light, rather than the phase-velocity, as must always be the case for any wave process involving a finite duration (there are no **infinite** sine waves in nature).

Action of a Lens

Many common optical devices contain not only mirrors and prisms with flat polished surfaces but lenses having spherical surfaces with a wide range of curvatures; in contrast with flat surfaces, such curved shapes are capable of forming real images on the opposite side of the lens. Convergent lenses are thicker at the center than at the edges while divergent lenses are thinner at the center.

When rays of light diverge from a single point in front of a convergent lens and continue as parallel rays then the point is called the primary **focus** and the distance from the center of the lens to the focus is called the primary focal length.

When parallel rays of light converge to a point <u>beyond</u> a convergent lens then the point is called the secondary focal point and the distance from the center of the lens to this focus is called the secondary focal length.

Many lenses use spherical surfaces, as these are easier to make and to analyze geometrically.

2.3.2 DIFFRACTION

Diffraction occurs when light, incident on the boundary of a second (opaque) medium, appears to 'bend' around the edge of this second medium, back into the surrounding, transparent medium. The effects of diffraction of light were first carefully observed and characterized by F. M. Grimaldi, who also coined the term *diffraction*, from the Latin *diffringere*, 'to break into pieces', referring to light breaking up into different directions. The results of Grimaldi's observations were published posthumously in 1665. Several qualitative observations [12] can be made of diffraction in general:

1. The angular spacing of the features in the diffraction pattern is inversely proportional to the dimensions of the object causing the diffraction. In other words: the smaller the diffracting object, the 'wider' the resulting diffraction pattern and vice versa.
2. The diffraction angles are invariant under scaling; that is, they depend only on the ratio of the wavelength to the size of the diffracting object.
3. When the diffracting object has a periodic structure, e.g. in a diffraction grating, the features usually become sharper.

The universality of diffraction whenever waves move through suitable media has been the strongest **evidence** for the view that light is an EM wave since optical diffraction is a directly observable phenomenon. Challenging this assumption has been one of the principle motivations in this paper since the world is actually discrete and, unlike waves, is not continuous.

Diffraction is usually classified into two categories: 1) situations where both the light source and the target screen are at very large distances from the diffractor or aperture; 2) configurations where either the light source or the target screen (or both) are at finite distances from the diffractor: the first case is called Fraunhofer diffraction and the second, Fresnel diffraction.

Fraunhofer Diffraction

Fraunhofer diffraction is readily observed by placing lenses around a narrow diffracting slit to focus the outgoing beam on a nearby screen. If a nearby point source is also used then it can be converted into an equivalent far source by placing a lens between the source and another (source) slit: the target screen exhibits a series of alternating light and dark stripes, on both sides of a central bright stripe, all parallel to the diffracting slit. It is the easiest form of diffraction to be explained by the wave theory as it only involves plane waves, as seen in standard graduate texts on optics [13]

Fresnel Diffraction

Fresnel diffraction is the simplest to observe experimentally and so, was the first form of diffraction to be investigated [14]: it only requires a small source of light (like a pinhole), the diffracting object and an observation screen. Alternating narrow bands of dark and light areas are seen whose shape varies (usually non-linearly) with the shape of the diffractor. It is this phenomenon that accounts for the lack of extreme sharpness delimiting the edges of shadows. When the diffractor consists of a circular aperture in an opaque screen, the image seen on the observing screen consists of alternating light and dark circles of reflected luminosity. A similar, complementary effect can be observed when the diffractor is a small opaque disk.

2.3.3 KEY FEATURES OF INTERFERENCE

The term **interference**, when used in an optical context, is used to describe diffraction effects involving the **recombination** of light from a finite number of coherent sources.

Coherence

Michelson wrote that he could not generate interference effects with ordinary light if the path lengths exceeded about a million wavelengths (about the length of the arms on his interferometer). He interpreted this to mean that ordinary light consists of **short bursts** of wave-groups emitted randomly from atoms, each lasting less than a billionth of a second. [15]

Scale

In order to detect appreciable interference the two-slit **separation** should be about equal to the wavelength; in other words, the difference in optical paths must be about the same size as the wavelength. Alternatively, one could say (here) that the difference in the travel times between two interfering optical paths is about one complete cycle of the source emitter.

2.4 POLARIZATION & GYRATION

2.4.1 POLARIZATION

A Twisted History

Erasmus Bartholinus of Copenhagen published a memoir in 1669 describing the optical properties of a certain transparent crystalline form of calcium carbonate known as *Iceland Spar*. The most astonishing property of this form of crystal is that it separates a single image into **two** distinct images when looked through in certain directions; he offered no explanation.

In 1672, **Huygens** passed light through two crystals of Iceland Spar rotating one with respect to the other and noticed that for some directions the second crystal did not double the two images from the first crystal. This meant that each of the two beams were somehow different to ordinary light. Huygens' own interpretation of the "double-imagery" induced by crystals of Iceland Spar, was that the crystal impressed a peculiar disposition into each beam while Newton thought that the crystal separated particles with different 'sides'. Huygens derived the double refraction property of the Iceland Spar from a geometric wave construction, extending his new construction method that he had also employed to explain refraction. Huygens realized that if the velocity of light varied with the direction, the spheres would deform to ellipsoids and thus was able to explain the refraction law for crystals such as Iceland Spar. This has remained the accepted explanation of polarization. It is vital to realize that Huygens was developing a theory of light propagation in special crystals, not æther.

In 1808, Etienne Louis Malus (1775-1812) noticed how the intensity of reflected light of the sun, when viewed through a crystal of Iceland Spar, varied when he rotated the crystal. He subsequently showed that the ability to polarize light was not restricted to very special crystals but could be present in reflections from any ordinary substance, transparent or opaque, except for polished metals. He came up with the *Malus law* that predicts the intensity of the light transmitted through a polarizer when the angle of the transmission changes (square law). This was refined in 1815 by David Brewster (1781-1868) who analyzed many different types of reflectors and in 1830 discovered that all reflections from polished metal surfaces produced elliptical polarization in the reflected light. He concluded that the index of refraction is the tangent of the angle of polarization and the reflected, polarized beam forms a right angle with the refracted beam. In 1811, Francois Arago (1786-1853) reported that the (clear) sky itself appeared polarized; he also presented evidence of circular polarization. Unfortunately, Jean-Baptiste Biot (1774-1862) presented two papers to the French Academy in the following year that offered a much more detailed analyses of these two examples of polarization, overshadowing Arago's original contributions.

Polarization & Wave Theory

Fresnel had shown in 1816 that cross-polarized light beams never exhibit interference but this was difficult to understand if light was viewed as a **longitudinal** oscillation (vibrating in the direction of propagation) like waves in air or water. It was not until 1821 that Fresnel viewed light as only a **transverse** oscillation with two orthogonal components; it was only then that he realized that polarization was all about phase. This was the ultimate break of the wave theory from all earlier ray theories. Ironically, Fresnel first analyzed reflection and refraction using his own dynamical interpretation of wave-like media excitations but only at the boundaries of different media and not everywhere throughout a homogenous medium. It was nearly another 50 years before the full 3D scalar wave equation was solved by G. Kirchhoff. All of the wave theorists posited an invisible fluid for the optical media and this was considered subject to velocity and density fluctuations occurring in long wave trains: pulses were always viewed as problematic due to their lack of obvious periodicity. These wave-based views formed the foundations of the 19th Century obsession with the physical reality of the universal, luminiferous **æther**.

2.4.2 OPTICAL ACTIVITY

Gyration

Michael **Faraday**, in his researches on magnetism, discovered the phenomenon of 'gyration' in 1845; this was the first time that a connection had been established between light and EM. When a beam of polarized light passes through a transparent substance then the plane of polarization is rotated when the beam is aligned with a strong magnetic field. The actual measure of rotation is proportional to the strength of the field and to the length of the optical path exposed to the magnetic effects. It is important to note that there is <u>no</u> gyration in a vacuum: the effect requires light to be passing through a material medium. It is also found that the degree of rotation varies with wavelength, Biot found that the rotation was nearly proportional to the inverse square of the wavelength so that violet light rotates almost four times (e.g. 50°) as much as red light (15°).

Magneto-Optics

In addition to this Faraday effect, there are three other observed effects demonstrating the interaction between light and matter when it is subject to powerful magnetic sources. They are the Zeeman effect, the Voigt effect and the Kerr effect. In 1896, Zeeman discovered that when a sodium flame is placed between the poles of a powerful electromagnet then the two yellow lines are considerably broadened. Soon after, in 1902 Voigt discovered that when a strong magnetic field is applied to a vapor through which light is passing perpendicular to the field, double refraction takes place. In 1888, John Kerr observed that when plane-polarized light is reflected at normal incidence from the polished pole of an electromagnet, it is slightly polarized elliptically with the major axis of the ellipse rotated relative to the incident vibrations.

Electro-Optics

There are three comparable effects when light is subject to powerful electric fields rather than magnetic ones. These are the Stark effect, Electric Double-Refraction and the Kerr Electro-Optic effect. It took until 1913 to demonstrate the analogue of the Zeeman effect with powerful electric fields, when Stark showed that a field of 100,000 volts/cm could symmetrically split the lines in the hydrogen spectrum. In 1924, Ladenberg observed the absorption of the sodium resonance lines when produced with and without a strong transverse electric field applied to the vapor at frequencies close to the absorption lines. Kerr actually discovered the electric effect in 1875 before his magnetic discovery. The effect was found in most transparent media; such as glass, water, organic liquids and gases. This diversity demonstrated that it was an orientation effect, not a distortion (or strain) result. All of the optical activity effects have been used to justify the view that light is an electromagnetic phenomenon as well as its ability to explain the propagation of light through free space and through matter.

2.5 ABERRATION & DOPPLER EFFECTS

2.5.1 STELLAR ABERRATION

In 1725, James Bradley discovered that the distant stars appeared to alter their **direction** when viewed from opposite points on the Earth's annual journey around the sun. This discovery (known as stellar aberration) not only confirmed Roemer's estimate of the finite speed of light but the Earth's relative motion with respect to the 'fixed' stars gave strong support for the <u>corpuscular</u> view of light moving relative to the Earth. This was later popularized by Eddington with his image of the running man holding his umbrella obliquely to avoid the raindrops. [16]

2.5.2 OPTICAL FREQUENCY (DOPPLER) SHIFTS

Short History

In 1842, the Austrian physicist, Christian Doppler (1803-1853) proposed an explanation for the difference in the color of light from certain stars that varied systematically over time. He suggested that these were actually binary stars rotating around one another and the light from each one changed its frequency depending on whether a star was moving towards or away from Earth. Three years later, this hypothesis was confirmed for sound waves by Buys Ballot, who showed that the sound's pitch was higher than the emitted frequency when the sound source approached him and was lower than the emitted frequency when the sound source receded away from him. In 1848, Fizeau discovered independently the same phenomenon for EM: this was another experiment that appeared to confirm that EM radiation was, in fact, a wave phenomenon.

Wave Theory Interpretation

Doppler's proposal was based on the assumption that light was a wave, so that all relative motion between source, medium and observer should generate these types of frequency shifts. In the case of light, (particularly after the idea of the æther was abandoned) only the relative difference in velocity between the observer and the light source needs to be considered. Astronomically, the Doppler effect is recognized by the fact that the stellar absorption lines are not always at the same frequencies that are obtained from the spectrum of an Earth-bound stationary light source. Since blue light has a higher frequency than red light, the spectral lines of an approaching astronomical light source exhibit a blue shift and those of a receding astronomical light source exhibit a red shift. [17]

2.6 NATURAL & ARTIFICIAL EM RADIATION

The term radiation describes any process in which either energetic particles or EM **effects** travel through a medium or across empty space. This paper will only address EM radiation, which is always characterized by its frequency – this obviously includes optical frequencies, when the EM radiation is called 'light'. In all EM radiation cases, the energy always *radiates* (i.e., travels outward in straight lines, in all directions) from its source. When EM radiation emerges from a heated material source, it is referred to as thermal radiation; it is generated whenever heat from the random movement of charged particles within atoms is converted to electromagnetic radiation. When the frequency of EM radiation is found in the range 10^{16} Hz to 10^{19} Hz, it is known as X-rays; they originate with non-nuclear atomic electrons. When the frequency is greater than 10^{19} Hz, it is usually called gamma rays; these emerge from certain atomic nuclei. It is always important to remember that high frequency EM radiation (with frequencies above the optical range) is undetectable by human senses and requires complex instruments to detect its presence (they are still very dangerous). All of these forms of EM radiation originally arose from natural sources – it required major advances in EM technology before humans were able to generate EM radiation directly.

2.6.1 BLACKBODY RADIATION

Thermal radiation was investigated extensively, primarily in Germany, in the second half of the 19th Century following Gustav Kirchhoff's invention of the "blackbody" (or BB) concept in 1859. Kirchhoff defined a heated object, which is in complete thermodynamic equilibrium, as a *blackbody* since it will absorb nearly all the radiation that falls onto it; when it emits radiation this is known as **blackbody radiation** (BBR). In 1879, Josef Stefan discovered that the radiation intensity or total radiation energy per unit time emitted from a BB was proportional to the fourth power of the absolute temperature of the body. Ten years later, Ludwig Boltzmann created a statistical model using the second law of thermodynamics that fitted this result.

In 1896, Wilhelm Wien measured the complete energy spectrum of a BB as a function of frequency of radiation produced. He discovered that the frequency at which the maximum energy is radiated becomes higher as the temperature of the blackbody is increased; this spectral distribution was independent of the type of material that was emitting the radiation. Both Lord Rayleigh and James Jeans then derived partial solutions of Wiens' findings at very low frequencies but increasing radiation of energy at higher frequencies led to the impossible result that the total energy radiated by a very hot body would be infinite. In 1900, Max Planck created his own 'quantized' theory of BBR that fitted the experimental results very well, with no 'ultraviolet catastrophe': this was the radical seed that grew into the quantum revolution.

2.6.2 HIGH-ENERGY EM RADIATION

In 1895, while working with tritium (a rare isotope of hydrogen) the German physicist, Wilhelm Röntgen (1845-1923) noticed a glow (or phosphorescence) on a nearby plate of coated glass and found a drastic change in cathode ray discharge rates. In one month, he had thoroughly investigated this new phenomenon (that he first called **X-rays**) and soon proved was high frequency EM radiation, an achievement that earned him the first Nobel Prize in Physics in 1901. Soon after in 1900, the French physicist, Paul Villard discovered rays more energetic than X-rays while investing radium. These were named **gamma** rays in 1914 by Ernest Rutherford after he proved that they too were EM radiation.

2.6.3 HERTZIAN RADIATION

In 1886, the young and ambitious German physicist Heinrich Hertz (1857–1894) developed a complementary pair of dipole transmitter and receiver devices, which he used to investigate remote EM coupling, hoping to find "a new scientific effect". By adjusting the frequency and distance between the two antennas, he was able to demonstrate resonance conditions, reflection and measure the speed of transmission between them. With these devices, Hertz was able to demonstrate in 1887 the existence of remote EM induction (asynchronous action-at-a-distance) in the receiving circuit. Since he was aware of Maxwell's EM theory, he then interpreted these results in terms of the production and reception of EM waves of very high frequency ('**radio** waves') as both Weber's and Helmholtz's electrical theories failed to predict EM waves.

3. THE NATURE OF *LIGHT – CLASSICAL THEORIES*

3.1 EARLY OPTICAL THEORIES

This section will review the earlier, historical attempts to explain the phenomenon of light; it will limit itself to so-called classical theories where the light is intense enough that no discrete manifestations appear – these are reserved for the next section. The two **metaphysical** viewpoints that have been in conflict for the first 200 years of optical thought were the particulate model and the continuous, or wave model. These two models are briefly examined here because they still form the basis of modern views on light. It is instructive to see how these theoretical ideas were organized to explain the various optical experiments that were given an increasingly numerical form as instrumentation techniques improved throughout this period. It is also shown that it was the introduction of more powerful **mathematical** techniques that gave the **wave** theory victory in this ancient 'metaphysical war' between the champions of the discrete and believers in the continuum.

3.1.1 HUYGENS' WAVE PULSES

Christian Huygens proposed the first modern theory of light in his famous optical book *Traite de la Lumiere*, published in 1690. Contrary to the belief, widely-held today, this was not a wave theory (with concepts like wavelength and frequency) but one involving a steady stream of **pulses**; he thought of light in terms of impulses transmitted from one *æther particle* to another. None-the-less, Huygens rejected the particle view of light as he believed that crossed beams of light must result in particle collisions, just like two flights of arrows – but this was not observed. His view of light as pulses of waves, allowed these waves to cross each other without scattering, as demonstrated by his observation of crossing water waves. Huygens invented the radical model of continuous ***secondary*** emission (of new spherical waves) at all points in any medium (including space itself) as light moved through the medium. The actual wave front was seen as the arithmetic sum of all the influences that were in phase together. He proposed that transmission was due to combining all the "disturbances" in the medium at every point from earlier points and then repeating the process forwards. This meant that in any finite volume of space there would be an infinite number of 'secondary sources'. This is now referred to as the "*Huygens Construction*". It is well suited to a mathematical analysis but Huygens could offer no physical mechanism to explain any of this activity. He was similarly defeated in his attempts to find a physical basis for polarization because his impulses were in the direction of the light's motion (longitudinal).

3.1.2 NEWTON'S CORPUSCLE FLUX

In response to Huygens' book, Isaac Newton published his own researches on light in his famous treatise *Opticks* in 1704. Newton proposed that light consisted of vast fluxes of tiny corpuscles that moved through space in straight-lines. Newton explained reflection and refraction by proposing that each light corpuscle (or ray) had an **intrinsic periodicity** (varying with color) that disposes it to be either reflected or refracted when it strikes a different surface; in other words, these special light corpuscles were (mysteriously) subject to alternating "***fits of easy reflection or refraction***". Newton described how he tried to measure the frequency of this oscillation believing that this frequency determined the color of the light in analogy with sound (Question 13 [18]). Newton considered the possibility of continuous waves but finally discarded this concept because of the rectilinear propagation of light. Newton, with his predilection for **atoms**, proposed his particulate model of light moving swiftly across space. He believed that the straight lines of reflection could only be explained by high-speed microscopic particles or corpuscles. He explained refraction by assuming that light corpuscles accelerated when entering a denser medium (such as glass) from a less dense medium, like air.

3.1.3 WAVES IN THE ÆTHER

Waves need a Medium

In the Encyclopedia Britannica's discussion of the wave theory of light [19] a wave is defined as: "any vibratory effect ***propagated*** through a **medium**". Before the 20th Century, this was always the understanding of scientists, who accepted DesCartes' model of the luminiferous æther. However, when Einstein 'abolished' the æther from his Special Theory of Relativity in 1905, he left his followers with EM waves that no longer needed any medium – no wonder, many of his contemporaries rejected this theory [20]. All observed wave-effects depend on the wave's energy, which is proportional to the average value of the square of the wave's amplitude. This means that the averaging over one complete time period removes all the phase effects associated with the wave: only by spoiling the wave can it be observed (a pre-quantum 'uncertainty' effect).

The French Æther

In the 19th Century, optical physics was most advanced in France, where the wave theory of light was strongly encouraged by analogies with sound propagation, which was itself a major part of the physics curriculum around 1800 at the new Ecole Polytechnique. The new revolution in optics began in 1810 when Etienne-Louis Malus used analytic geometry to create algebraic formulas of Huygens' Construction of double refraction that he then confirmed by accurate measurements. Malus himself still viewed light as consisting of individual rays, some of which took different paths through optical media based on this intrinsic asymmetry, which could be rotated along with changes in the direction of the rays. In 1818, Augustin Jean **Fresnel** (1788-1827) won the prestigious "Diffraction Competition", set by the French Academy of Sciences, by developing an integral formulation of Huygens' principle of secondary wavelets. These analytic formulas for predicting the minimum interference fringes were confirmed by his innovative experimental measurements, made to an improved level of accuracy. Although this innovative approach won this optical competition, several of the eminent judges (including LaPlace, Biot and Poisson) were still unconvinced of the reality of the wave theory. Fresnel's theory established the mathematical ascendancy of the wave theory (by its extensive use of analytic geometry) over the 'emissionists', who could only offer qualitative and simple mathematical (arithmetic and geometric) explanations. At all times, the wave theorists simply viewed a 'ray' as a geometrical line connecting a point source to any point on the wave front. Since the 'emissionists' explained diffraction as the result of material forces arising in the edges of real objects on the particles of light, Fresnel countered with the simple suggestion that interference could be created by combining light from two mirrors without relying on any edges. History shows that Fresnel played a major role in the switch from a corpuscular to a wave model of light. It is interesting to note that C. Fabry, the first biographer of Fresnel, described him as "*a great **engineer** – a man who, when faced with a concrete problem, knows how to find the best solution: the one that leads to the best result with the minimum of time and effort*."

Young's Æther Wave

In 1801, Thomas **Young** (another British autodidact) performed his famous **double-slit** experiments, which showed that recombining light from the two slits could result in bands of darkness. He then created his own mathematical basis for the wave theory of light in 1802. Young was convinced that the results of his double-slit experiments demonstrated that light was a vibration (or wave) in an all-pervasive optical æther (elastic medium) where two independent oscillations could be moving in opposite directions canceling each other completely (destructive interference). At first, he could not explain light polarization as the æther was thought to be either a gas (like air) or a liquid (like water) that only supported longitudinal variations. A few years later (independently of Fresnel and with the new knowledge of crystal structures) he proposed that the optical æther behaved like a solid, supporting **transverse** variations that could explain polarization.

Fresnel Diffraction

Initially, Fresnel's explanation (like Young's) of near-diffraction or 'object-diffraction' (outside a narrow object, like a wire) involved interference between only two rays, one arriving directly from an intense 'point' source and the other **re-emitted** from the near-edge of the narrow object. Fresnel extended this mathematical analysis to "inner" (or in-shadow) interference by considering two rays from **both** sides of a small diffracting object. Both Fresnel and Young found that the first "outside" maximum occurs at an optical path difference of one full wavelength (or period) when it 'should' have been at a half-wavelength – this implied that the re-emission required a half-period delay or that it introduced an extra 180º phase-shift.

An Ætherial Obsession

In the 1830s, the new wave theory was enthusiastically adopted by several influential, young British mathematicians, who subsequently promoted the new theory in their scientific journals. The few British 'emissionists' (like Brewster and Potter) were never convinced of the truth of the wave theory but by 1840 were effectively marginalized, finding it difficult to get their research published. Potter continued to explain all the results of the wave theorists by simply replacing the wave front with synchronized bursts of light particles. An extensive discussion was offered earlier [21] on the concept of the æther, as this was central to Maxwell's physical model of EM. It is one of the many ironies of science that after publishing his very successful *Dynamical Theory of Gases* in 1860, involving the random collisions of point particles, Maxwell still expressed reservations about the reality of molecules to G. G. Stokes, Lucasian Professor and Secretary to the Royal Society. This was due to the widespread "British preference for a continuum theory of matter, in which gross matter was ultimately reducible to the motions of an all-pervading ætherial medium." This metaphysical assumption was widespread in England after 1800 even though the greatest British hero of science, Sir Isaac Newton had presented his own philosophy of nature in terms of particles. This ætherial preference was also the belief of the leading British scientist, Lord Kelvin, who viewed particle dynamics as a useful approximation to the real æther – "*the only suitable medium for a God of infinite power*". Indeed, he viewed "abstract dynamics" as only applicable to an idealized world with conservative forces and no friction.

3.2 LIGHT AS A MATHEMATICAL FIELD

This sub-section is included to illustrate how the modern theory of classical electromagnetism is a blend (mish-mash?) of physical concepts and mathematics that has been constructed from several disparate theories beginning first in 1860 and appearing over the following fifty years.

3.2.1 ELECTROMAGNETIC WAVES

MacCullagh's EM Æther

The Irish physicist, James MacCullagh (1809-1847) proposed an important Lagrangian model of the luminiferous æther in 1839 when he hypothesized that the potential energy of an element of æther was proportional to the square of its absolute rotation (or 'curl') [22]. Astonishingly, this bizarre proposal of frictionless, rotational distortions pervading all of space was an excellent solution to the optical experiments involving light's reflection, refraction and polarization, illustrating the wide divergence between mathematical and physical explanations. Only a few physicists with an interest in the history of their subject know that this was a key inspiration for Maxwell's own EM theory. This background was covered in UET2 [23].

Maxwell's Theory anticipates Light

In his 1865 'Dynamical' paper [24], Maxwell did **not** prove that light was an electromagnetic vibration but first assumed this result from the beginning by starting with an 'elastic' medium (the æther) pervading all of space that could support undulations by transmitting motion from one part to another with great, but still finite, velocity. Maxwell extended the ideas of electric polarization ($\underline{D}$) and induced magnetization ($\underline{B}$) from real, material media to the vacuum of empty space. From his earlier, failed attempts based on explicit properties of the æther, Maxwell knew which equations he needed to retain that would convert to the key differential equation known as the wave equation, which he needed as his representation of 'light'.

Hertz re-derives Heaviside Equations

As a specialist in the study of Maxwell and 19th Century physics, Harman has written [25]: "*The generation of EM waves was <u>not</u> a straight-forward deduction from Maxwell's concept of molecular motion in the æther. Nor did Heinrich Hertz deduce the possibility of generating EM waves from any simple interpretation of Maxwell's theory of the EM field. Hertz was working within the framework of Helmholtz's electrodynamics, a theory of physics, which in its essentials diverges radically from the suppositions of Maxwellian theory. Helmholtz's electrodynamics assumed all physical effects could be deduced from interaction energies (potentials) <u>between physical bodies</u>, while Maxwell's theory aimed to reduce effects to <u>local</u> states of the mediating field or æther. Helmholtz had constructed his own theory around Riemann's 1858 conclusion that the action of electric masses on each other are propagated with the velocity of light. Ironically, in 1884, Hertz working from a generalized action-at-a-distance theory arrived at a similar set of free-space 'field' equations as Heaviside, illustrating the complementary nature of these two approaches."* This new confusion was absorbed by Hendrik Antoon Lorentz (1853-1928) who, from his 1875 dissertation, strongly preferred the particulate view of matter. So he adopted Hertz's equations for a stationary EM æther and linked them to a discrete structure of matter (electrons) via 'his' Lorentz force in an unsymmetrical manner, where æther oscillations effected the electron but not vice-versa [26]. Fortunately, Hertz failed to realize that Maxwellians believed only pulses could be generated, not waves, with radiation only 'escaping' from the open terminals or small gaps.

Maxwellians failed to anticipate Generated Radiation

As one of the first 'disciples' to follow Maxwell, Oliver **Heaviside** was philosophically opposed to the asynchronous direct action (or ADA) view of the world and so welcomed the spark experiments of Hertz as a verification of the field viewpoint (in his words: "*It killed those 'spooky' potentials*."). It is also ironic that Maxwell never anticipated the practical aspects of his own theoretical research. Since Maxwell viewed light as the consequence of a microscopic interaction between matter and the æther, he never considered the possibility of generating EM waves by rapidly varying electrical current [27]. The second generation: " '*Maxwellians' (like Heaviside, FitzGerald and Lodge) thought of Hertz's dipole as specifying regions where EM fields stopped, not as objects that controlled or produced EM fields*." Indeed, FitzGerald, agreeing with Maxwell's æther-based model of EM, dissuaded his friend, Oliver Lodge from attempting this type of electrical experiment in 1883, leaving it to Hertz to succeed with this groundbreaking experiment five years later. As Buchwald summarized [28] this monumental failure: "*One scarcely exaggerates in remarking that field theory <u>deterred</u> Maxwellians from discovering electric waves. … Maxwellians ignored sources almost completely and thought about radiation in terms of initial values and constraints imposed by boundary conditions*."

J. J. Thomson (a keen mathematical follower of Maxwell's theory) wrote extensively [29] on EM radiation in 1893 but completely misunderstood the significance of Hertz's dipole experiments, which were not susceptible to the kind of deep, mathematical analysis that Maxwellian electrodynamics could bring to simpler geometrically shaped objects in isolation, like spheres and cylinders [30]. While Hertz's dipole could be viewed as a composite object of one cylinder connecting two spheres – this also illustrated the difference in attitude to EM sources. Thomson recognized that the resonator must oscillate for many thousands of cycles but believed that the transmitter circuit's oscillations should fade away very rapidly. This appeared to be confirmed soon after in 1891 when Bjerknes performed a series of measurements on similar dipoles, which indicated that the Hertz oscillator only vibrates about a dozen times before its amplitude becomes insignificant due to almost all its energy being radiated away, whereas the receiver gradually lost its energy due to conduction losses. This story illustrates the power of working with appropriate concepts that map reality accurately; a primary motivation of this theory.

Special Relativity builds on 'Maxwell-Hertz'

As Einstein-scholar Arthur Miller describes [31] at the beginning of his magisterial study of this famous paper: "*Hertz considered (the four vector equations) axiomatic, i.e. he made no attempt to derive them*." Einstein's 1905 paper *On the Electrodynamics of Moving Bodies* [32] begins its major (second) part on electrodynamics by transforming the 'Maxwell-Hertz Equations'. This reference illustrates the young Einstein's lack of in-depth knowledge of the history of EM. Equally, Hertz made no attempt to justify his revised time-dependent pair of equations, where he simply replaced the partial time derivatives with full time derivatives when he extended his four vector equations to another reference system in relative motion. As Hertz knew, in empty space these equations were identical to the Maxwell-Heaviside Equations, which were the direct result of **assuming** that the æther had intrinsic dielectric and magnetic characteristics. As Hertz also knew, these EM equations lead directly to the wave equation for the electric and magnetic vector fields that propagate at the speed of light when they include the light-speed parameter *c*, which again he had introduced explicitly and axiomatically.

3.3 LIGHT AS AN ENERGY TRANSFER

3.3.1 THE ENERGY CONCEPT

Leibniz's vs. Newton's Worldviews

Newton created a mechanical model of the world involving interactions between particles and in his theory of gravity he began with interactions between remote particles or ***action-at-a-distance***. Leibniz was Newton's principal rival [33], in philosophy as well as in mathematics, dismissing Newton's model as absurd. Leibniz modernized Aristotle's metaphysical concepts of energy and potential. Aristotle defined *en-ergia* as "beings, at work" (i.e. existents that are active in the world), which arise or become manifest into active existents from *potentia* or "those awaiting to become". The Hamiltonian and Lagrangian formulations of physics, which lie at the heart of wave mechanics and QFT, are direct descendants of Leibniz's emphasis on energy. For over one hundred years now, the energy approach has been the dominant approach in physics; it seems to have exhausted its potential to extend the frontiers of physics, so that a return to Newtonian ideas seems timely and appropriate. It might be thought that Newton's corpuscles, rather than energy, were a better example of '**beings, at work**'.

Modern Origins of the Energy Concept

It was the study of current electricity (as well as his knowledge of Rumford's 1798 cannon-boring paper) that inspired **Joule** in 1843 to view heat, not as a substance ('caloric') but as a state of vibration that could be converted into useful mechanical work, motivated by the attempt to maximize the conversion of heat from fuel into useful work [34]. The energy concept was introduced into science after 1840, once it was realized that the caloric model of heat [35] was no longer tenable. "*The North-British founders of the then-new science of energy in the middle of the 19th Century (William Thomson, Macquorn Rankine, Clerk Maxwell, P. G. Tait and James Joule) were all explicitly motivated by their strongly held Christian views to replace LaPlace's (and Newton's) model of nature (based on action-at-a-distance between point particles, which had been associated with atheism, since Democritus) with a universe of continuous matter: ("something, everywhere") possessed of kinetic energy*." The two "laws of thermo-dynamics" (a word invented by Thomson [36] in 1854) reinforced their Protestant view of a world that could only be altered by the ultimate 'Prime Mover' (**God** himself). The first law (the Conservation of Energy) implied that there was only a fixed amount of the "*primary move-ability*" in the universe, while the second law (the progressive unavailability of useful energy) reflected the Calvinist sense of inevitable decline, which was being opposed by atheist Herbert Spencer's popular view of evolutionary progress. Both John Herschel and W. K. Clifford were critical of the first law, viewing it as no more than a tautological statement since the immeasurable potential energy could always be introduced to account for the apparent changes in kinetic energy [37]. Even the deeply Christian, Michael Faraday objected to the new energy doctrines as they too implied a mechanical model of nature involving only matter and motion, while he viewed his God as the master of ubiquitous power, rather than as an engineer or architect.

Helmholtz's 1847 memoir *Erhaltung der Kraft* (*Conservation of Force*) was based explicitly on the view [38] that: "*all action in nature can ultimately be referred to as attractive or repulsive forces whose intensity depends solely on the distances between the interacting points*." Implicit in Helmholtz's proof were the assumptions of instantaneous forces and the idea that total kinetic energy must always be conserved.

Maxwell's Disciples reify Energy

As noted, Maxwell called his major 1865 EM paper a "**dynamical**" theory because he always assumed that "the space in the neighborhood of electric and magnetic bodies contains matter-in-motion", which he viewed as "undulations of an ætherial substance" that can also be set in motion, eventually communicating this motion to gross matter. It was Maxwell's so-called "disciples" (Heaviside, FitzGerald and Lodge) who redefined Maxwell's EM field theory. Their key move was to **reify** the idea of energy, based on the false notion that energy had identity that could be followed at all times – a view totally adopted by the German energeticists, like Ostwald [39]. Even Maxwell's friend and colleague, William Thomson treated this view with unreserved contempt, retaining the view of energy as a mechanical property of real particles (the view adopted by the present theory) – a definition that can then be measured in terms of work done. Maxwell had rejected the Riemann theory of EM based on asynchronous action-at-a-distance (ADA) but unfortunately had used an argument constructed around ideas of instantaneous movement of both ends of a '**rigid rod**' – ironically a "thought device" used later in 1905 by Einstein in his relativity paper. Maxwell was convinced of the correctness of his own theory only on the measurement of the constant c, ironically first determined by his rival Weber in 1855. This was actually not determined accurately until 1878 – one year before Maxwell's death. The new emphasis on **fields** was because the use of the EM potentials, with the energy restricted to the electrical currents alone, was (as Heaviside recognized) too close to Weber's own (rival) instantaneous action-at-a-distance EM theory [40]. Mathematicians have always preferred analysis – especially, the mathematics of the infinitesimal.

Reviving Action-at-a-Distance

A life-time Einstein scholar has written that: "*Action-at-a-distance was unintelligible before Newton, became perfectly intelligible by the end of the 18th Century and again unacceptable after Maxwell*." [41]. This illustrates the shifting sands of metaphysical **fashion** running through the history of physics. It is one of the goals of this neo-Newtonian programme to restore this revolutionary concept to the forefront of theoretical physics, in its asynchronous (non-instantaneous) form, even though local field theories presently reign supreme but are now confronted with the mystery of 'quantum entanglement'.

Energy – Matter in Motion

Since its introduction as a powerful concept in the middle of the 19th Century, the idea of energy [34] has evolved into a **metaphysical primitive** threatening the primary role of matter in physics – particularly since Einstein attempted to prove their equivalence [42]. This theory returns to Newton's view: energy is a state **of** matter, it is always "matter in motion" (i.e. kinetic energy) whether visible to humans or not. Potential energy is a concept introduced to reduce the effects of asynchronous interactions between matter, at two different locations and times, to a single time and then it only needs to be characterized by its relative spatial position. This is a mathematical convenience but it hides the role of prior motion and its latent capacity to create future relative motion [43]. Therefore, in this theory, energy will never be viewed as an existent i.e. an independent entity with its own existence – a view that has consumed the modern, mathematical physicist.

3.4 PROBLEMS WITH CLASSICAL LIGHT MODELS

Both Newton's particle model of light and Huygens' wave model are both macroscopic analogies of what humans perceive as macroscopic aggregations of atomic phenomena. Since the reality of atoms was not decided upon until around 1900, it was quite understandable that extending these analogies down to finest levels of detail seemed to be more than plausible. This section is included because there is still a widespread belief amongst physicists that light is '**really**' a wave that sometimes exhibits particle-like properties. In fact, each of these sub-models of light has its own major conceptual problems without trying to merge them into some mysterious kind of existential contradiction.

3.4.1 PROBLEMS WITH THE PARTICLE MODEL

Light knows the shortest Path

When light is viewed as an independent entity ejected from the emitter in all directions it remains an unexplained mystery. How this "lonesome traveler" knows how to find the fastest path to the absorber, particularly when the absorber is found in a single atom that could only be reached by multiple sub-paths, some of which are in found in different media.

Light Speed experiments destroyed the Emission Model

The terrestrial measurements of light speed in both air and water dealt a deadly blow to the 'emissionists', who followed Newton in viewing light in terms of particles emitted from hot sources. The particle model had predicted that the speed of light would vary with refractive index and travel faster in denser media. Once the refractive index was seen as the ratio of speed in vacuo to speed in the medium this model collapsed. The wave theory correctly predicted that light speed varied inversely with refractive index.

3.4.2 PROBLEMS WITH THE WAVE MODEL

Light needs a Medium

Only the localized properties of light are ever observed directly in optical experiments, such as the tracks of photo-electrons created by the transmission of X-rays through a cloud chamber. Wave-like effects, especially interference, are only math interpretations of collective phenomena: the waves themselves are never seen. In marked contrast to today's physicists, the natural philosophers of the 19th Century were altogether much more consistent in recognizing the proposition that: "*if light is a real wave phenomenon then something must be supporting the propagation of the disturbance*." By the 1820s, the wave view of light was firmly accepted and thus the luminiferous æther was viewed as a necessary reality – a position that many of these scientists, maintained until the end of their lives (even well into the 20th Century, such as A. A. Michelson). It was only as theoretical physics adopted a phenomenological stance, where equations were seen as a complete model of reality, did the idea of the æther die out along with its older proponents; mathematicians are quite happy to adopt a Platonic view of their timeless symbols representing the ultimate reality. Now we only have "force field densities" (whatever they may **be**?).

Problems with Huygens' Construction

The Huygens-Fresnel Principle is adequate to account for a wide range of optical phenomena. Huygens first proposed that every point to which a luminous disturbance reaches becomes a new source of a spherical wave; the sum of these secondary waves determines the form of the wave at any subsequent time. He was able to provide a qualitative explanation of linear and spherical wave propagation, and to derive the laws of reflection and refraction using this principle, but could **not** explain the deviations from rectilinear propagation that occur when light encounters edges, apertures and screens, commonly known as diffraction effects. Almost 140 years later, **Fresnel** showed that Huygens' principle, together with his own principle of interference, could explain both these diffraction effects and the rectilinear propagation of light. To obtain agreement with experimental results, he had to include additional arbitrary assumptions that the secondary waves oscillate at a quarter of a cycle out of phase with respect to the primary wave and that the magnitude of the secondary waves are reduced by the inverse of the wavelength. He also needed to include an additional obliquity factor, $K(\theta) = (1 + \cos\theta)/2$ for the relative angle θ to the primary wave. These assumptions had no obvious physical foundation but led to predictions that agreed with many experimental observations, including the Arago Spot. It is now recognized that this method of analysis applies to any problem of coherent (same phase and frequency) propagation in the far-field limit and for near-field diffraction. Melvin Schwartz has pointed out that to consider each point on a wave-front as a new source of radiation "*makes no sense at all*", since (he argues correctly): "*We now know that light does not emit light; only accelerating charges emit light*".

Problems with Temporal Direction

Huygens' always assumed that the secondary waves travelled only in the "forward" direction of time and it was not explained in the theory why this is the case. Even though it was later shown by Gustav **Kirchhoff** (1824-1887) how this principle could be deduced from Maxwell's Equations, this does not actually resolve the question about "*backward*" propagation of waves, because Maxwell's Equations themselves theoretically allow for advanced as well as retarded potentials. The principle is deeply flawed because it fails to account for the directionality of the wave propagation in time, i.e., it doesn't explain **why** an expanding spherical wave continue to expand outward from its source, rather than re-converging inward back toward the source (an experimental fact)?

Problems with Spatial Dimensionality

Huygens' Principle is now understood to apply equally to any locus of constant phase (not just the leading edge of a wave disturbance), all propagating at the same characteristic phase speed; this is <u>not</u> limited to wave propagation. For example, if a light flash occurs for a brief, time duration then someone viewing the flash at a distance will see it for exactly the same duration. Similarly, the fact that we see sharp images of distant stars and galaxies is attributed now to Huygens' Principle. However, as has been pointed out by Kevin Brown [44] that this principle is valid only in spaces with an **odd** number of spatial dimensions. Dropping a pebble into a calm pond will create a circular wave on the two-dimensional surface of the pond that will propagate outwards and Huygens' Principle predicts that the pond's surface to be perfectly flat, quiet both outside *and inside* the expanding spherical wave. In fact, the surface of the pond inside the expanding wave (in this 2D space) is *not* perfectly calm; its state continues to differ slightly from its quiescent state even after the main wave has passed through. This excited state will persist indefinitely, although the magnitude rapidly becomes extremely small. Huygens' Principle is actually trying to provide a mechanism to explain why wave spread equally in all directions.

Problems with Aberration

James Bradley, the third Astronomer Royal and a contemporary of Newton, discovered in 1725 a small shift in the direction of nearby stars when viewed from opposite points in the Earth's orbit – a phenomenon now known as 'stellar parallax'. The tiny angular difference (an aberration α, of about 20 seconds of arc) indicated a measurable first-order effect $\alpha = v / c$ where v is the average tangential velocity of the Earth around the sun. This experiment "*implies that the motion of the Earth and the motion of the (star) light are <u>independent of each other</u>. However, when the motion of the light is the propagation of a disturbance in a medium then the motion of the Earth does <u>not</u> affect the medium. The medium remains absolutely fixed*." Thus, any possible æther is <u>not</u> dragged along by the Earth's motion – this was the basic model adopted by Maxwell in his ætherial theory of light.

George Airy (1801-1892), the seventh Astronomer Royal, repeated Bradley's experiments in 1871 but with the telescopic tube now filled with water, where light is considered to move 25% slower than in air. Now the Earth moves even further (relative to Bradley's air-filled telescope) as the light descends through the telescope. Airy was surprised to find no change in the angle of aberration. Allowing for the refraction of light as it enters the water-filled tube, this new result can only be interpreted, in an æther-based model of light, if the æther is partially dragged along by the Earth by an amount equal to the Fresnel 'drag co-efficient' $(1 - 1 / n^2)$, where n is the index of refraction for water (about 4/3).

Other first-order optical experiments performed in the 19th Century to measure 'æther drift', such as those by Arago (in 1810) and Fizeau (in 1851), also suggested that the æther was being partially dragged along by matter (e.g. glass or water) moving at Earth's orbital speed. Thus, the null second-order result of the Michelson-Morley experiment (MMX) was in complete disagreement with these expectations, as the null result implies a "full-drag". It was this **contradiction** that should have condemned all æther theories to the scrap heap – however, Michelson (and many others) still believed fully in Maxwell's EM æther theory! The observable effects of stellar aberration are readily interpreted with a corpuscular model of light but cause a major problem for any wave theory of light unless the optical æther is regarded as stationary through which the Earth moves. This was the original motivation for the MMX project as <u>originally suggested by Maxwell</u>, himself. The null result required physicists around 1900, who desperately desired to save their beloved wave theory of light, to invent the distortion of the space and time parameters between moving inertial reference frames, known as the Lorentz transform (see UET4§2.0).

Phipps criticized Eddington's famous explanation using the 'umbrella in the rain' model for understanding stellar aberration as this explanation is only valid for real, discrete objects (like rain) that travel across space and not for wave propagations in a medium (as Eddington should have known).

Multiple Wave Modes

The only real examples of observable waves, for example water waves, are conceptual simplifications – singular nouns (or collective nouns, like army) referencing trillions of trillions of individual molecules. Cynthia Whitney has pointed out that the wave model of light needs a bizarre combination of **modes** to describe the complete processes involved [45]. Emission requires an expanding spherical wave; energy-conserving long-distance radiation needs plane waves while final absorption requires a converging spherical wave. She writes: *"The localized photon model is adequate for emission and absorption but needs enormously extensive photons to explain coherence and entanglement.*" This magical photon-creature would emerge as a point, spread its wings across most of space as it stretches its body to gigantic proportions and then shrinks back to a point; no wonder physicists have stopped trying to visualize the photon.

Field theories are also filled with '**plane waves**' that pervade the whole of space, from one end to another, usually across all of time. These are a great mathematical simplification as they enable Fourier transforms to be taken of any phenomena that vary in space and/or time. But it takes a 'giant', like Pauli [46], to point out the physical paradox their usage generates when he acknowledged: "*a plane wave is a mathematical idealization as it is **infinite** in extent and has, therefore, **infinite** energy*." This does not bother mathematicians even though, if the energy of the plane wave is anywhere, then it must be everywhere. Pauli has been one of the few major physicists to even express concern that the continuum basis of EM field theory (CEM or QED) conflicts with the demonstrated **discrete** nature of reality (e.g. e and m) [47]. This deep **ontological** awareness has been reflected by few modern authors, who mostly work around this central obstacle by defining special mathematical limit procedures (like the delta function) for concepts like charge. This definitional conflict at the heart of classical EM is sharpened by the experimental fact that any attempt to measure the EM 'fields' can only be accomplished using corpuscular test charges.

The issue here is that it is theoretical physicists (i.e. mathematicians) that define the "explanation" for experimental observations. When mathematicians are convinced that a particular body of mathematics (in this case, continuum calculus) **must** be the correct tool to describe certain phenomena in nature then they are compelled to believe that nature exemplifies their symbolic scheme. This is the fallacy of **reification** – the making real of symbols that has been at the heart of Platonism since its inception. It is an "explanation" that only satisfies mathematicians. Ordinary folk (and commonsense) **deny** that there is any **reality** to the concept of the square root – no matter how many times they are shown the Pythagorean proof.

3.4.4 PROBLEMS WITH ENERGY TRANSFER THEORY

The 'Conservation' of Energy

In 1847, Helmholtz derived his 'proof' of the Conservation of Energy at any **one** instant of time based on **instantaneous** (spatially dependent) **central** forces [38]. These key qualifications are usually forgotten and this 'principle' was raised (by the proponents of energy) to a fundamental law of nature. In contrast, UET offers the **Bi**-Conservation of Energy (reflecting the finite duration of interactions between pairs of electrons at **two** different times) where the conservation of energy and/or momentum between the two electrons are **not** complete until their interaction is complete.

3.5 THE METAPHYSICS OF LIGHT

Ontology

Natural philosophers have thought systematically about the nature of existence or **ontology** for several thousand years. It is now recognized that we organize our shareable views in terms of networks of verbal concepts. Many of our concepts form hierarchies, where many similar examples are abstracted into a 'higher' concept. One of the deepest concepts in western thought is centered on the idea of '**things**'. Like all basic concepts that relate to reality, the multiple instances of reality are grouped into classes. One of these base classes is the concept of ***entity***. An instance of an entity has independent existence from all other entity instances; in other words, the disappearance of one entity instance does not remove any other entity instance. This is contrasted with ***relationships*** that depend on the existence of entities. For example, one man does not die because another person ceases to exist but his marriage is over when his wife dies. Reality only consists of instances of entities and their interactions. Each (instance of an) entity must interact with other entities to have any claim to existence. If any object is not interacting with the rest of reality, then how could it claim to have any existence? At the macroscopic level, human interactions are just as valid a part of reality as the interaction between any two electrons. Existence is an intrinsic quality of entities (an unqualified scale-less property) and does not depend on their quantity or size: in contrast to Positivism that treats the world exclusively from the human viewpoint (on the arrogant assumption that "man is the measure of all things"). It was this arrogance that dismissed the reality of atoms because they were too small to be seen.

Neither 'free' particles (without interaction) nor 'light' (interactions without entities) can be said to exist. Both light and energy are **not** entities (real things) but <u>relationships</u> between material objects. Historically, light has been abstracted away from its sources and given an existence of its own. Philosophically, light should be the abstract term used for **both** the electric charges **and** their interactions. This integrative (or synthetic) viewpoint is much harder to visualize (and describe mathematically) than just its isolated parts. In a similar manner, energy cannot be viewed without its context; e.g. the target particle with its motion (and kinetic energy) defined <u>relative</u> to another (observing) particle. Light does not exist – it is a mental abstraction. This is the 20th century version of ***nominalism***: the reification of an idea because it has been given a name: it is the confusion between the thing represented and the thing used for the representation. This is the fallacy known as the "Map and the Territory". The originator of general **semantics**, Alfred Korzybski [48] came up with the key phrase: "<u>*A map is not the territory*</u>" meaning that a map can describe a territory in some similar structure that allows us to traverse the land. This gives us a useful tool but that our perception of the map can never **equal** the territory, only our version of it: our map. All symbolism acts in this manner; all information comes to us second hand – science needs to always remember this distinction. For example, the concept of 'giving' can be never discussed without introducing the reality of the giver and the receiver, while the 'gift' may be a real object (like a rose) or an action (like a smile). Similarly, light is the phenomenon of spatial transfer of time-sensitive displacements (or momentum) between remote electric charges.

Epistemology

The higher animals, like humans, build very useful representations of the external world into the structures of their nervous systems, particularly in their brains. The most powerful representation involves mental imagery, which is a construction of the visual system. The raw sensory data in this mode is absorbed by the frontal part of the brain (eyes) and passed through many layers of processing in the rest of the brain. In fact, more of the brain is dedicated to visual processing than any other sensory mode. One critical insight has arisen in the last few years: our visual system is not simply an optical system or even a complex camera: the images that are finally stored are <u>massively processed forms of digital information</u> and bare almost no correspondence to the simple one-to-one images mapped between sources and screens in the external world. It is ironic that all of this information involves light, whose nature we know so little about, and visual memory, which we know almost nothing about. The macroscopic size of humans compared to atomic dimensions and our slow thinking (0.1 seconds for neurons to recover) compared to atomic transition times means that all sensory-based knowledge of the micro-cosmos (atoms and smaller) must be statistical. However, this does <u>not</u> mean the reality of the world at those scales must be statistical: this would be another example of the representational fallacy of confusing the map with the territory; again, metaphysics must be made explicit. The 'emissionists' viewed light moving through optical systems in terms of rays: these could be described by simple straight lines in two-dimensional representations of optical systems involving transparent slabs, lenses and mirrors. This mapping is today therefore called **geometric optics** and is the usual manner of introducing optics to new students of physics. Some of the analysis here will use this simplified representation while acknowledging that this implies no commitment to the nature of light itself. It must always be remembered that humans never see rays or waves of light. In suitable (usually simple) sets of circumstances, we can infer 'paths' between sources and remote locations of electrical excitation. In all cases, lines and wave fronts are <u>mathematical</u> constructions to aid our visualization of the situation, which in this theory is always viewed as ***asynchronous action-at-a-distance***.

Physics

The spatial variation of mass-points, in physics, is the most powerful <u>model of reality</u> that acknowledges the discrete nature of matter: from atoms to galaxies. The wave model is actually a simpler mathematical scheme as it assumes a single *plenum* or medium of existence; it is very useful for calculating the randomized (or at least, <u>averaged</u>) collective effects of enormous numbers of interacting particles. Interestingly, both the wave and particle models of light can be traced back to DesCartes and his **mechanical** philosophy that <u>touching</u> was the only way to effect any change in the world. He viewed light as a real substance: either particles of matter in motion or as pulses of motion transmitted through a material medium (æther) [49].

In his *Treatise on EM* [50], Maxwell fell into the classic 19th century error of separating EM forces from mechanical forces: "*Electromotive force is always to be understood to act on electricity only, not on the bodies in which electricity resides. It is <u>never</u> to be confounded with ordinary mechanical force, which acts on bodies only and not on the electricity in them*."

He took this further so that <u>partial</u> differential equations were to be used to describe energy in the form of fields; in contrast with the <u>total</u> differential equations for action between remote particles in motion. This required a distinction to be drawn between the <u>forms</u> of energy, which he viewed as some kind of existential primitive idea (God?). Einstein was aware of this problem and later viewed this dissatisfaction as just due to the field theorist's necessity to still include Newton's material points (i.e. electrons) as part of the dual representations of physical reality – a dualistic problem still present today [51]. Unfluckily, he was trying to retain the wrong concept: most (not gravity) mechanical forces are ultimately electromagnetic.

Although acknowledging Weber's (instantaneous) action-at-a-distance theory of EM interactions as equally mathematically valid, Maxwell could not view it as fundamental because of the "*mechanical difficulties involving velocity-dependent forces between particles*" – something that is not seen today as a problem for users of the 'Lorentz' force! Maxwell viewed the EM field as real undulations in an ætherial substance of finite density that permeated all gross matter while interactions with this gross matter merely modified the motion of this æther, which was viewed as the repository of equal parts linear elastic and kinetic energy, **in transit** between source and excited matter.

Metaphysically, Maxwell constructed his 1864 EM theory around the concepts of **force fields** defined in some mysterious **æther**; since he also relied on Coulomb's electrostatic law for the electric component of his force fields he had to introduce his concept of the 'displacement current' to derive the wave equations for both of these fields propagating in a vacuum. In contrast, in 1867 L. V. **Lorenz** derived all of these wave equations using **only** retarded scalar and vector potentials defined between remote electric charges, with no need to interpose a continuous 'field' between the source and target charges [52]. It is this successful (but now almost totally forgotten theory of EM) that is one of the principal roots of the present theory.

After describing (and severely criticizing) the classical theories of light, especially the wave and Maxwellian EM theories, it is now time to introduce the '**dark horse**' that has been stalking this story: this is the discrete behavior of light and its explanation in terms of Einstein's most revolutionary concept – the light quantum, or '**photon**'.

The present research programme has rejected from its very beginning the implicit assumption that light is an entity. The fourth paper in this series showed that this was **the** metaphysical mistake that lies at the very foundation of Einstein's Special Theory of Relativity [53]. This same fundamental mistake lies behind almost every single theory of 'light' – indeed, in Einstein's case this is not surprising as Maxwell's theory of light as variations in a fixed medium was the explicit starting point for Einstein's theories of relativity.

4. QUANTUM OPTICS & PHOTON THEORY

4.1 PLANCK'S BLACKBODY THEORY

For 30 years, from 1895 onwards, Max Planck developed his theory of cavity ('blackbody' or BB) radiation based on his model of absorption and re-emission of EM radiation by a one-dimensional, simple-harmonic 'oscillator'. In 1900-01, he recognized that in order to derive his radiation law (which would match the experimental results) he needed to introduce a mathematical constraint that the energy ε of this device needed to be directly related to its 'natural' frequency ν, through the linear relationship: **ε = *h* ν**. The factor *h* was a universal constant that Planck first called the 'element of action' but in 1906, he renamed as the 'quantum of action'. Although Planck rejected the programme of the energeticists, he always approached thermodynamics "from general principles" as he had no specific models of matter or even radiation. His only mechanism was the '**resonator**', which he conceived (mathematically, following Hertz in 1889) as a damped, oscillating current, which vibrated sympathetically in a tuned response to an oscillating, external stimulus. Until 1909, Planck always viewed this EM process as **continuous** (i.e. classically) but in that year he acknowledged Ehrenfest's criticism was correct: his own claim of the role of the resonator in equilibrating the radiation across all frequencies was wrong. In 1906, Ehrenfest and Einstein (separately) were the first to point out that Planck's final radiation formula could not be derived without first **restricting** the resonator's energy to **integral** multiples of $h\nu$; i.e. $\varepsilon = n\ h\nu$. These objections by two young physicists were ignored until Lorentz confirmed the need for the revolutionary **energy discontinuity** in 1908. This new viewpoint was soon adopted by the leading senior radiation researchers, such as Wien, Jeans and Planck himself, between 1909 and 1910. Einstein wrote in 1909: "*Planck's radiation law is incompatible with its own theoretical foundations*", pointing out that Planck's derivation was only valid in the low frequency limit where: $h\ \nu << k\ T$. In 1910, Planck publicly committed for the first time to the need for discontinuity in BB radiation while admitting for this purpose: "*one will not have to give up the Principle of Least Action but one will have to abandon the* ***hypothesis*** *of the universal validity of the Hamiltonian differential equations*." In 1911-12, he redeveloped his own BB theory by assuming that only the emissions from his now undamped oscillator were discontinuous. He continued to reject the 'quantum of energy' until 1923, when in the fifth edition of his *Lectures on the Theory of Thermal Radiation* he finally dropped his own "second theory". Planck never had any physical theory to support his ad-hoc quantum of action but in a letter to Ehrenfest in 1905, Planck hoped that it would be eventually explained by electron theory (in an allusion to Lorentz's electron theory of 1900). Planck thought it might be related to the new "quantum of electric charge *e*" since "*h* has the same dimensions as e^2/c" (this is the starting point of UET's own quantization – see UET5). The focus on quantization began in earnest in 1907 with Einstein's own quantum theory of the specific heats of solids and dramatized by Bohr's atomic theory of 1913 (both directly inspired by Planck's BB theory). The extended search for generalized quantum conditions reached its peak with the (separate) proposals of Sommerfeld and Wilson in 1915.

4.2 THE PHOTOELECTRIC EFFECT

In 1887, Heinrich Hertz discovered the photoelectric effect [54], so called because light rays can impact the flow of electric current. He observed that when ultraviolet light was shone onto metallic electrodes the voltage required for sparking to take place was lowered. In 1899, Philip Lenard, who had been a student of Hertz, showed that electrons were ejected from the surface of a metal plate when it was struck by light. In 1902, he then showed that when a polished metal plate was directly illuminated by light that the speed of the ejected electrons was independent of the light intensity – increasing the intensity (over a range of 1000 times) only increased the number of electrons ejected but not their speed [55]. He also showed that the energy of the ejected electrons varied directly with the frequency of the illuminated light: this could be explained by a corpuscular model of light but not by any form of wave model.

In 1905, Einstein proposed an explanation for this effect by assuming that light was composed of discrete particles, or light-quanta, which collide with the atomic electrons and by further assuming that all the energy of one photon was absorbed by one electron so that it could be ejected from the metal's surface. This explanation was based on Planck's energy-frequency relationship ($\varepsilon = h\nu$) – the first use of *h* outside of BBR [56]. Millikan spent the next 10 years experimentally confirming this prediction. Einstein never discussed the source of this photon or why he believed Planck's emission hypothesis could be simply extended to the free EM field. This explanation of the photoelectric effect was incomplete, for it failed to include the fact that the temperature of the metal surface was later seen experimentally to affect the energy of the emitted electrons; this feature was included in a revised theory created by Fowler in 1930 [57]. Later experiments with the gaseous form of the photoelectric effect indicated that more electrons are ejected **parallel** to the electric polarization vector and **not** longitudinally in the direction of light propagation, **refuting** the idea that 'photons are like billiard balls'.

4.3 EINSTEIN'S PHOTON-GAS THEORY

Einstein's explanation of the photoelectric effect was actually the second part of his first, revolutionary paper of 1905 [56] with the tentative title: *On a heuristic point of view concerning the production and conversion of light*. The definition of ***heuristic*** is key, as this word means 'unjustified' or '*incapable of justification*'; unfortunately, this has been the fate of this central concept (light-quanta) ever since. In this paper, he retained the idea of equi-partition of energy, in a body at absolute temperature T in thermodynamic equilibrium (i.e. each independent 'mode' contributed an energy kT, where k is the usual Boltzmann's constant). He rejected Planck's classical frequency distribution law and created the light-quantum 'guess' from an analogy between radiation in the high-frequency regime ($h\,f >> k$T) and a classical gas of ideal (non-interacting) material point particles using Wien's exponential law for the energy-density per unit volume for a specific frequency f. It is particularly interesting to see how [58] Einstein introduced this key idea: "*Monochromatic radiation of low density behaves in a thermodynamic respect* ***as if*** *it consists of mutually independent energy quanta of magnitude hf.*" He went on to state his 'heuristic' principle: "… *the laws of the generation and conversion of light are also constituted* ***as if*** *light were to consist of energy quanta of this kind*." The light-quantum hypothesis is an assertion about a quantized property of free EM radiation while the heuristic principle extends these new properties of light to the interaction between light and matter [59]. Einstein returned to these views with two radiation papers published in 1909 with his conviction that Planck was on the right track, based on very good agreement between Planck's theoretical estimate for the electronic charge e and two independent experimental sets of measurements [58]. The first paper derived a formula for the mean-square fluctuation of the energy fluctuations in an infinitesimal frequency range of BBR in contact with a material body in thermal equilibrium. His formula consisted of two terms: one corresponding to classical wave theory and a new term involving the energy quantum as point-like particles. It was this result that inspired Einstein to seek a unified EM solution to this new apparent ***duality*** of light. Ironically, Einstein rejected the complementarity solution for electrons when it was introduced in the new QM in 1925. When Einstein first introduced the idea of the quantization of light in 1905 he used the term *Lichtquanten* or **light-quanta**. He did not consider that these quanta had momentum until 1916 when he proposed the phenomenon of stimulated emission of radiation [61]. It was here that he proposed that each quantum of frequency f carried momentum, $\mathcal{P} = h\,f\,/\,c$. in the direction of the light-wave. This addition corresponded to Planck's relativistic mass-energy formula for a particle of zero rest mass, with total (relativistic) energy $\mathcal{E}$, that is it satisfied the equation: $\mathcal{E} = \mathcal{P}\,c$ or, in terms of an 'effective' mass, $\mathcal{M}$: $\mathcal{E} = \mathcal{M}\,c^2$. Stark had actually independently proposed this formula for the momentum of a light-quantum in 1909 [62]. In retrospect, history shows that Einstein abstracted both the energy and momentum components of the photon concept entirely from considerations of statistical mechanics, particularly using his well-used techniques of fluctuations around average values.

4.4 THE STIMULATED EMISSION OF RADIATION

Since no atom can exist for long in isolation, any excited state of an electron in the atom will only persist until its excess energy can be communicated to another, remote electron. When an atom decays without the presence of any external EM radiation, it is said to be due to 'spontaneous emission' and is the explanation of the phenomenon of fluorescence. Stimulated emission of radiation is the process by which an excited atom can be 'triggered' to emit EM radiation by the presence of external radiation of a similar frequency. The extra radiation is created with the same phase, polarization and direction of travel and very similar frequency as the original; i.e. it is coherent. If the resultant radiation is multiply reflected so that it traverses the same group of excited atoms many times then a cascading or multiplier effect may be produced: a process known as 'optical amplification' as the output intensity is then greater than the intensity of the external, stimulating beam. This effect is one of those rare phenomena in physics that was predicted first by a theoretical calculation. Einstein investigated this possibility in 1916 [61] when he imagined a mix of atoms interacting with EM radiation – again, all in thermal equilibrium. He considered energy transitions between groups of atoms in two different energy states with every excitation induced only by the EM radiation but de-excitations also arising spontaneously as well as being induced by the external radiation. Since populations in thermal equilibrium are distributed exponentially (i.e. proportional to $\exp[-\,E/kT]$) this approach led to an EM radiation density formula very similar to Planck's radiation law and could be made identical by assuming the universal relationship: $E_j - E_k = h\,f_{jk}$. This was exactly the condition that Bohr had assumed in his theory of atomic spectra when atoms emitted radiation of frequency f_{jk}. In deriving this result, Einstein had to explicitly consider the direction of the momentum exchange between the atoms executing a transition via EM radiation. This forced him to use 'needle rays' (i.e. directed line-of-center rays of zero width) and not spherical waves. This was the clue he needed to see that light-quanta could exchange momentum as well as energy [62]. In 1905, it was the lack of energy dispersion of ejected secondary X-rays that gave Einstein the idea that EM energy was localized. Unfortunately, he not only assumed that the emission and absorption processes were integral, he extended this localization idea to the propagation across space.

4.5 PROBLEMS WITH THE PHOTON MODEL

Although it was Einstein who first suggested the idea that radiation behaved as if it were composed of a finite number of localized energy quanta in 1905, it was not until 1926 that G. N. Lewis proposed the term "***photon***" for a quantum of light in a paper entitled: *The Conservation of Photons*. Ironically, it is now known that the number of photons is not conserved.

4.5.1 PROBLEMS WITH PLANCK'S RADIATION MODEL

Kirchhoff's Mistake & Planck's Fix

Since Kirchhoff (like most other scientists in 1860) believed in the reality of the luminiferous æther, he had no difficulty equating the quality and intensity of this æther in the cavity of a heated solid with the surface effects of the body at the same equilibrium temperature as æther was assumed to pervade both space and matter homogenously. This view has misdirected research ever since from the reality of the heated surface to the empty cavity enclosed by this surface. This perspective led Planck in 1900 ("with his profound aversion to the molecular approach") to create his oscillator model of cavity radiation and his necessary '**guess**' for the relationship between the entropy of this oscillator (S) and its average energy (E), namely: $\partial^2 S/\partial E^2 = a/E(E+b)$. Planck abandoned his usual thermodynamic approach and adopted Boltzmann's probabilistic concept of entropy for a large but finite collection of these oscillators, each with a unique frequency f and a finite energy: $\varepsilon = h\,f$. This key equation was sufficient to 'derive' his energy-distribution equation: $E[f] = \varepsilon / (\exp[\varepsilon/kT] - 1)$, which initiated the quantum era. Planck later admitted that this energy quantum was "***an act of desperation***" to fit the facts [63]; this was a mathematical '**fix**' to derive the energy spectrum equation that had been generated by his fellow experimentalists in Berlin. In 1906, Einstein pointed out the inconsistency of treating EM radiation (i.e. Maxwell's æther theory) as both continuous oscillator energy and as partitionable energy quanta. Einstein chose (on this occasion) to back the discrete view and suspected the validity of the Maxwell classical EM theory at the microscopic level. Planck never provided a physical model of his energy transfer model of radiation; his 'oscillators' were simply introduced as equivalent mathematical fictions to represent the fluctuations. He was moving firmly along the new phenomenological path recommended by Ernst Mach and the **Positivists**. As a result, the most important equation in the evolution of quantum theory in the 20th Century: $\boldsymbol{E = h\,f}$ was **never** given any physical explanation. Indeed, no one ever asks **how** an oscillator of shorter duration per cycle (higher frequency) has time to 'pick up' more energy than one that takes longer to go from its minimum to maximum displacement. This critical omission has certainly contributed to the "shaky foundations" of all of quantum theory.

Bohr contradicts Planck

Planck's final (1912) revision of his radiation theory treated absorption as a continuous (classical) process but he proposed that each one of his atomic oscillators only emitted all of its energy according to a probability based on the radiation density at the tuned frequency f of the oscillator [64]. Each oscillator would accumulate energy until it reached one of the harmonic values (nhf), where n was a positive integer. Rather than assuming that the EM energy itself was discrete, he assumed that only discontinuous emission was needed. However, when developing his own theory of atoms one year later, supposedly based on Planck's radiation theory, Bohr proposed that both the emission and absorption of radiation must be discontinuous.

4.5.2 PROBLEMS WITH EINSTEIN'S PHOTON MODEL

Rejection of the Photon Model

In 1906, the young von Laue (then Planck's assistant), offered an insightful comment in a private letter to Einstein on his controversial 'photon' suggestion of treating high-frequency radiation as particulate: "*Radiation does **not** consist of light-quanta but only **behaves as though it did** during energy exchanges with matter*." [65]. Contrary to today's perception that the photon concept entered physics in a blaze of glory, Einstein's photon proposal **only** became generally accepted after the discovery of Compton scattering in 1922 – ironically, Compton (as a Maxwellian) never accepted this interpretation of 'his' effect. Furthermore, neither Philip Lenard, who first investigated the photoelectric effect with Hertz, nor Robert Millikan, who was awarded the Nobel Prize in Physics in 1923 for confirming Einstein's descriptive equation, believed in Einstein's theory of light quanta as an explanation of this effect. Pais [66] believed this widespread rejection of the light-quantum concept at this time was the deep commitment by the physics profession to Maxwell's EM field theory. A widespread myth is circulating that Einstein's 1916 paper led directly to the invention of the laser – this is not so, the critical feature of such devices is that the stimulated emission occurs exactly **in phase**. Einstein's statistical approach only spoke about similar energies, all phase knowledge is lost in such aggregate mathematics while phase-coherence was not mentioned in this paper.

Photoelectric Ambiguities

Willis Lamb showed in 1969 [67] that the quantization of the EM field was **not** necessary to explain the photoelectric effect; it was only necessary to use Fermi's frequency rule (modified from Bohr's rule) that h f = (E_{init} – E_{final}). It was only the developments in quantum optics in the early 1980s that allowed direct evidence for a single photon to be demonstrated; prior to this the inability to control the emissions from a light source had actually prevented the light-quantum being 'seen' for 80 years from when its existence had first been proposed. Even then, its existence was **inferred**, rather than 'seen'.

The 'harmonic paradox' is never mentioned in discussions of the photoelectric effect. This is the possibility that a lower frequency f / n (where n ≥ 2) than is normally needed to initiate electron ejections could combine serially (n times) to then provide sufficient energy to liberate bound electrons from the metal. In other words, why is the light-quantum **integral**?

The photoelectric effect is found to be effective only at optical and X-ray frequencies but falls off rapidly at higher, gamma ray energies (above 100 MeV). There is almost no discussion of why fractional energy of the gamma ray should not be available when interacting with the metallic electrons as is found in free-space Compton scattering. So the question still remains: why only 100% and not multiples or fractions of the energy available in the light quanta are used to liberate the ejected electron?

Single Photons

It is extremely difficult for humans to comprehend the atomic scale (exemplified by the enormous number of electrons – about 10^{24} in a gram of matter), so it is equally difficult to grasp the number of photons we experience at the macroscopic scale. A standard 100 watt light bulb has been calculated to emit about a million billion (10^{15}) visible photons every second. This means that any real experiment involving only one or a few photons is an extremely difficult, technical challenge.

It was not uncommon for many years (e.g. Feynman in his popular lectures [68]) to reference experiments involving single photons. In fact, this was not demonstrated experimentally until 1974 when John Clauser [69] showed unequivocally that a four beam splitter could distinguish, to a high degree of statistical accuracy, between the predictions of quantum field theory and classical (or semi-classical) theories of light by measuring twofold <u>coincidence</u> rates from a single source. Clauser concluded that a QFT radiation field containing only one photon brought into interaction with two separated atoms will never produce more than one photoelectron, so that this result can only be interpreted as being induced by a particle model of light that must be either transmitted or reflected by a half-silvered mirror. This experiment used a mercury source that was excited by electron bombardment and high-speed electronics with a one nano second resolving time with 26 hours of exposure. Clauser concludes this important paper with the apparently sardonic comment: "*The classical (unquantized) Maxwell equations thus appear to have only limited validity*." Such subtleties seem to have escaped most physicists.

A necessary step in conducting such 'single-photon' experiments is the availability of very sensitive photo-detectors; some of the most powerful ones today use silicon avalanche photo-diodes. At the heart of all single-photon sources lies a single nanoscopic object, which is small enough so that a transition between its electronic states corresponds to a light emission from a single atom. In order to increase the directional efficiency of such devices they are embedded in an appropriate optical cavity with dimensions comparable to the optical wavelength. This ability to 'generate a single photon on demand' always requires control of a single emitting atom. Physicists at the Max Planck Institute of Quantum Optics were the first to achieve this in 2007. They used a magneto-optical trap (focused lasers) to ultra cool a few Rubidium atoms in a 3D cavity inside a vacuum chamber. These atoms were then stimulated by a sequence of laser pulses from the side to emit a stream of single mono-energetic photons from the cavity.

Double Photons

The recent availability of reliable sources of single photons means that even more sophisticated experiments can now be conducted in situations involving two photons. It is found that when two **independent** photons (that are indistinguishable: same frequency, direction and polarization) are sent into a beam-splitter, in such a way that when one photon is transmitted it ends up in exactly the same mode as the other photon, which is always reflected because when both are transmitted or both reflected, they cancel out. In other words, the two photons '**coalesce**' [70]. When two photons coalesce they constitute a single quantum object, in effect, they become 'entangled' and this persists even when they are far apart such that no classical model based on 'local realism' is able to explain this effect.

Outstanding Questions

The photon model fails to explain how, in an attractive interaction, the photon can 'remove' momentum from the electron, which is pulled back towards the attractive center. This would only be possible if advanced effects were permitted (QED).

Even the latest beam-splitting experiments involving 'single photons' like those using **Mach-Zehnder** interferometers, are still being analyzed in terms of a traveling entity that has the characteristics of both a wave and a particle that suffers self-interference along common 'light-paths'. No physicist today seems prepared to challenge the wave-particle orthodoxy, even though these two concepts are mutually contradictory: a particle at every moment of time is localized at **one** single point in space while the concept of waves (particularly plane waves) exist **everywhere** throughout **all** of space at any single time. This raises the most important question in quantum physics – how can this **contradiction** (not paradox) be resolved?

Finally, there was never any explanation offered by Einstein (or any of his later expositors) as to where the emitted photon's energy comes from when a static point electron (with no internal or kinetic energy and invariant rest mass) emits a photon to accelerate another, remote electron. This is surprising as the orthodox position in physics, even today, is the "Conservation of Energy" at **all** times and the electron cannot convert any of its rest-mass to energy as this is its minimum mass always.

Failure to Prove $E = Mc^2$

As a continuum theory, Einstein's final presentation of EM was developed throughout, in terms of spatial functions per unit volume. As Jefimenko has pointed out in his alternative approach to relativity [71], this '**density**' approach automatically smuggles in the Lorentz transformation to preserve the invariant (discrete) electric charge on the point electron:

$$e' = \int dv' \mathcal{L}[u]\, \rho[x'] = \int dv\, \rho[x] = e \ , \quad \text{where } \mathcal{L}[u] \text{ is the Lorentz factor } (1 - u^2/c^2)^{\frac{1}{2}} \text{ when the relative 1D speed is u.}$$

Von Laue's 1911 proof and Klein's 1918 generalization [72] both involved integration of the energy-momentum density tensor even though the conservation law ($\partial_k T^{k\mu} = 0$) implies that the volume integrals of the of the stresses T^{kj} are zero in the rest frame. For a closed system, the total energy and total momentum then transform as a four-vector, which has exactly the same form as those of a particle. This is no more sophisticated conceptually (but not mathematically) than suggesting (like Einstein) that the Maxwell EM energy-momentum radiation-density relationship is "acting **as if** it were a particle."

When Einstein proposed the most famous equation in science in 1905, it was a timely compromise between the traditional priority of Newton's concept of particulate concept of mass and Ostwald's radical proposal of 1891 to abolish mass in favor of the new concept of energy as the **primary substance of nature** [73].

Ohanian has described [74] how Einstein failed **seven** times to prove that the mass-energy formula was a universal relationship. He notes that even Einstein, in his final scientific autobiography published eight years before he died, failed to mention this equation anywhere – a most mysterious omission for his most famous scientific contribution. Ohanian also points out the no one was ever awarded the Nobel prize for either this equation or even the Special Relativity theory. Even Ohanian has difficulty discussing the failure of Einstein's original proof in 1905, referring to it only in one of his own footnotes. He there describes how Einstein assumed that the formula for the kinetic energy of a classical body could be directly extended to high energies, when only the relativistic mass formulas had been derived for a single, point particle subject to (incorrect) longitudinal and transverse forces [75].

5. LIGHT AND QUANTUM ELECTRODYNAMICS

Phenomenology

Scientists before 1900 had no real knowledge of the atomic nature of matter. It was therefore understandable that they would try to explain the phenomena of physics simply in terms of relationships between the observable parameters – an approach known as **phenomenology**. Unfortunately, this **math-only** approach has been adopted as the norm in theoretical physics, where a set of equations is considered a sufficient explanation of the phenomenon, even when the equation's symbols have no observable analog. This is the primary reason why scientists in the 19th Century debated whether light was really a wave or a flux of corpuscles. In each case, they were reifying the symbols used in their mathematical models, either waves or rays. String theorists are just the latest in a long line of mathematicians repeating this all the way back to **Plato**.

The rejection of instantaneous mathematical and conceptual schemes in favor of asynchronous interactions has been the basis of this EM research from the very beginning; this obviously means that the historic focus on the motion of a single particle (or 'field point') subject to external 'forces' is also rejected in favor of the interaction **between** particles. [76]

It is the contention of this programme that **EM theory** was beginning to get on the right track in the 19th Century but went completely off the rails with the introduction of the field concept by **Maxwell** that has influenced physics ever since. This direction was reinforced by Hertz's failure to demonstrate that his EM radiation experiments could be explained by the EM theory of Herman von Helmholtz, who had been Hertz's mentor and was the most powerful figure in German physics at that time. As Helmholtz wrote in 1871, he was adamantly opposed "*to deducing the principles of theoretical physics from purely hypothetical assumptions as to the atomic structure of bodies*." This was a powerful, public rebuke to his chief archrival, Wilhelm **Weber**, who could provide full explanations of all macroscopic EM phenomena with his electrical force 'law' between point-like, universal charges. Since Maxwell had also failed to provide any physical explanation for his EM equations, there developed an unspoken agreement between the most powerful academic specialists in electromagnetism in both England and Germany that a phenomenological (mathematics only) approach to EM theory was the only acceptable way forward. This set the stage for this **style** of theoretical physics to be adopted in all areas of 20th Century physics.

The UET theory owes much to Weber's almost forgotten action-at-a-distance theory of electrodynamics but incorporates also Gauss's revolutionary suggestion that the EM interaction is **not** simultaneous. In addition, a few extra ideas have been added; the following table might prove helpful in situating the present theory (**UET**) amongst these older models.

	Maxwell	Helmholtz	Weber	UET
Locus	Cell ($d^3\underline{x}$)	Cell ($d^3\underline{x}$)	Point ($\underline{x}$)	2 Points ($\underline{x}_1 - \underline{x}_2$)
Focus	Field point	Macro body	Charged particle	Two Electrons
Substance	Æther	Charge density	Electric charge	Electrons
Range	Next cells	Remote cells	Remote points	Remote Electrons
Interaction	Force density	Force density	Point Force	Impulse
Key Concept	Field	Potential energy	Remote action	Remote Interaction
Composition	3D integral	Many bodies	Pair-wise points	Two electrons
Temporality	Single time	Single time	Single time	Two times
Time Interval	1 infinitesimal	1 infinitesimal	1 infinitesimal	Δt_1 & Δt_2
Action	Continuous	Continuous	Continuous	Discrete

The present theory situates the 'paradox' of light as "**wave or particle**" in the pre-Twentieth Century predilection for falling back on phenomenology – the invention of equations relating measurable parameters without first developing a conceptual schema to understand the entities involved. Only **after** the equations were accepted were attempts made to link the symbols to higher-level concepts. Since the phenomenon of light is so fundamental, it has resisted mechanical models and modern physics has usually described the effects purely in mathematical terms. The discovery of the electron forced theorists to acknowledge that these new particles must play a key role in EM but were not prepared to give up on the wave mathematics of Maxwell's field theory. This blend of particle concepts (electrons) and wave mathematics (EM fields) became known as electrodynamics. When the mathematical ideas of modern quantum mechanics (QM) were merged with the mathematics of classical fields the result became known as quantum field theory (QFT). Even particles eventually were described in terms of quantum fields so that the final version emerged in a form now known as quantum electrodynamics (**QED**).

5.1 QUANTUM ELECTRODYNAMICS (QED)

Quantum Mechanics

Very soon after the discovery of the electron and Rutherford's planetary image of the atom, the first version of quantum mechanics (QM) arose with **Bohr**'s model of the hydrogen atom in 1913. This model was the first to give a quantitative explanation of the discrete spectrum of 'hot' matter. This established the focus of 20^{th} century physics: **light** and **matter**; that reached a climax with the theory of quantum electrodynamics (QED) around 1950. The standard model of QM was developed by mathematical physicists around 1925, primarily by Heisenberg, Dirac and Schrödinger, which were all seen to be alternative formulations of the idea that observable quantities could no longer be represented by algebraic variables, as had been the mathematical technique used since Newton. Although Dirac's approach stayed closest to its roots in classical mechanics, it was Schrödinger's formulation as partial differential equations ('wave mechanics') that became the most popular, as this method retained the closest links to the mathematics of classical mechanics. This method introduced the idea that an electron could be represented by a complex continuous function of its space and time co-ordinates $\Psi[\underline{x}, t]$. Since Ψ was the solution of the wave equation for a free electron this offered a mathematical 'explanation' of the observed periodic behavior of electrons. Since this function was defined for all locations $\underline{x}$ at all time t, it behaved like a mathematical field. All of these approaches used the concept of the **Hamiltonian** function that described a fixed number of particles with only <u>instantaneous</u> forces acting between them and therefore derivable from a continuous potential energy function of space. As all these theorists knew (but chose to ignore): the Hamiltonian approach was incompatible with the principles of special relativity, as one particular time variable must be selected as the canonical conjugate of the Hamiltonian function.

Darwin's Lagrangian

In 1920, C. G. Darwin invented a Lagrangian that (to order v^2/c^2) eliminated the radiation modes from electrodynamics. This resulted in a quantum theory of EM that was formulated as an <u>instantaneous</u> action-at-a-distance theory involving velocity-dependent components [77]. This was an important intermediate step in the evolution of a full QFT.

A Brief History of QFT

QED really began with Dirac's famous paper on the relativistic theory of the electron [78], which was actually a quantum field theory (QFT) as the electron was represented everywhere by a field function. This was based on Pascual Jordan's explicit proposal that all physical phenomena, both electrons and their EM fields, should be viewed as quantum fields. Dirac invented quantum field theory (QFT) in 1927 when he proposed the radical technique of '<u>second quantization</u>', where Schrödinger's electron wave function $\Psi[x]$ was transformed into a new role as a mathematical operator. This was replaying his earlier hand of 'doubling up' Pauli's (2x2) spin matrices into his own (4x4) relativistic matrices [79]. This time, Dirac repeated the original or 'first' quantization transformation of converting the electron's algebraic momentum variable (P) into a quantum operator $-ih_D\,\partial/\partial x$ by converting the mathematical function $\Psi[x]$ into an equivalent (matrix) operator $\mathbf{C}[x]$ while the complex conjugate function $\Psi^*[x]$ was converted into the Hermitian conjugate operator $\mathbf{C}^\dagger[x]$: these were interpreted as the particle destruction and creation operators of an electron at the 4D position x. Dirac first applied this technique to create a quantum version of Maxwell's classical field theory of electromagnetism (CEM) [80]. This provided a mathematical representation of Einstein's photon concept, with the wave features associated with propagation and the particle aspects associated with the interaction of light with matter. This type of continuum mathematics required introducing the infamous 'delta' function $\delta[x]$ that Dirac probably remembered from his earlier electrical engineering studies of Oliver Heaviside who used it to derive his discrete 'step' function $\theta[x]$ [81]. Even Heaviside may have extracted it from the study of his own favorite mathematician Joseph Fourier, who used a similar function in 1822 [82]. As soon became clear, this new QFT involved non-observable, intermediate (or 'virtual') states that do not conserve energy while all event probabilities were calculated to be infinite – quite embarrassing since such values must be limited to the real range of zero to one [83]. Once again, Dirac had 'doubled up' – extending his electron-filled model of the vacuum that appeared empty now to a photon filled model of empty space that was equally invisible to experimental inquiry until extra, external energy was supplied. Bethe and Fermi formalized these ideas in 1932 [84] with their model of forces as short-lived excitations being exchanged as 'virtual' particles that could borrow energy for a short time and were subject to 'repayment' according to Heisenberg's uncertainty principle. No mechanism or source of this borrowed energy was proposed. This mathematical model of inter-particle interaction based on independent fields inevitably led to the idea of self-interaction. By design, this new approach combined relativity theory with local, single-time particle Hamiltonian field densities to represent the EM interaction with a single electron at <u>every</u> point in space. The mathematical expression for this interaction: $\mathbf{H}_I[x] = e\,\Psi^\dagger[x]\,\gamma_\mu\,\Psi[x]\,A_\mu[x]$, was simply a direct extrapolation from Maxwell's classical EM field theory, with A_μ now representing the quantized EM field i.e. a 'photon'.

In his 1932 paper on relativistic quantum mechanics [85] Dirac proposed that in optical scattering a single electron must interact with both the incoming and outgoing EM waves at a single point – once again demonstrating his commitment to the highly localized **point** model implied by a particulate view of the electron. Although EM radiation could be resolved into plane waves, he showed that Coulomb forces were implicitly involved in his 1D model and pictured them as "*vibrations of an intervening medium transmitted with a finite speed*" [86]. In 1932, Podolsky and Fock extended Dirac's model to 3D and obtained the Coulomb interaction term with the correct sign. They also showed that Dirac's QFT was mathematically equivalent to the QFT of Heisenberg and Pauli published a year before [87] and which Dirac had rejected on the grounds that it was "too ugly". [88] As always, he preferred a geometric (visual) approach rather than an algebraic approach.

Feynman, Schwinger & Tomonaga

All the quantum field theories of the 1930s agreed that quantizing Maxwell's EM theory of light was legitimate because these equations had a classical limit. These theories ultimately coalesced between 1946 and 1949 into three mathematically equivalent versions [89] created by Richard Feynman, Julian Schwinger and Sin-Itiro Tomonaga (an equivalence shown by Freeman Dyson) that are usually referred to as quantum electrodynamics or **QED**. Interestingly it was Dirac's many-time formalism (written with Podolsky and Fock) that was the inspiration for both Schwinger's and Tomonaga's covariant QFTs.

The Electron Magnetic Moment

When Dirac developed his relativistic theory of the electron he first used it to see how this might change the interaction between the electron and the EM field [90], which was initially treated in the classical Maxwell manner with 4-potentials. Dirac created a model Hamiltonian for non-relativistic electrons (i.e. slow-moving) that to lowest order added a term that was proportional to the magnetic field and so was <u>interpreted</u> as the electron possessing both a magnetic moment μ and angular momentum or spin $\underline{\mathbf{S}} = \frac{1}{2}\, h_D\, \underline{\sigma}$. The 'free' electron's magnetic moment was shown to be: $\mu_0 = e\, S / mc$. By 1930, Dirac [91] had calculated the lowest order (or e^2) effect of his polarized vacuum of virtual positrons for $\mu = (1 + \alpha / 2\pi)\, \mu_0$.

The Lamb Shift

At the end of WW-II, there occurred one of the most important experiments in 20th Century physics. This was the accurate measurement of the energy difference between several lines in the spectrum of atomic hydrogen performed by Willis Lamb [92] in 1947. These lines or frequencies, part of the 'fine structure' of the hydrogen spectrum, correspond to the orbital electron making transitions from several second-order to first-order excited states (principal quantum numbers n = 3 to n=2). Both the relativistic planetary model pioneered by Sommerfeld in 1916 [93] and Dirac's relativistic equation applied to the hydrogen atom [94] predicted <u>equal</u> changes in the fine structure of the hydrogen spectrum to first-order in α $(e^2/h_D\, c)$. Although these tiny shifts (from the Bohr predictions) were only 2 parts in a 100,000 the new microwave technology that had been developed in the war for radar was sufficient to distinguish even smaller deviations from the Sommerfeld / Dirac calculations with the spherically symmetric orbital slightly higher in energy than the elliptical orbital. It was this very tiny anomaly that inspired a generation of theorists to improve on Dirac's theory predicting these newly measured energy levels in the hydrogen atom, using the Dirac hole-theoretic approach and the latest versions of their own QFTs.

Success of QFT

All QFT calculations are enormously complicated and very difficult to confirm, indeed most contemporary calculations are done inside the depths of vast computer programs. All of this mathematical 'machinery' has been used to calculate tiny corrections [95] to theoretical quantities, such as the electron's "magnetic moment" μ from its 'free' value ($\mu_0 = 1$) to a value 1.001147 μ_0. Ten years later, this value was recalculated by Peterman et al, who showed that several arithmetic errors had been made so that $\mu = 1.0011596\, \mu_0$. These so-called fourth-order ($e^4 \approx \alpha^2$) effects were 'confirmed' by experiments twenty years later, even though Dirac's second-order was already very close at: $\mu = 1.001162\, \mu_0$ (an 8th digit difference).

5.2 FEYNMAN'S ELECTRODYNAMICS

It was Feynman's theory that ultimately became the most popular and canonical version of QED. Although he was deeply motivated to produce a theory that was self-consistent and free of infinities, his new theory was built on old foundations. It only became finite using the controversial technique known as '**renormalization**'. However, Feynman's theory was much easier to calculate with than any of his rivals and his diagrammatic representation of electron 'scattering' was an instant success with all who used it. It is for these reasons, that Feynman's version of QED will be the focus here.

5.2.1 FEYNMAN'S INTUITION

All of Feynman's rivals gave precedence to the reality of the field but Feynman, like Dirac, always preferred the concept of the particle – a view shared by this programme. However, by 1950 it would be fair to say that the field view had triumphed.

Feynman & Wheeler

Feynman based his own formulation of QED on his PhD thesis [96] in 1942 at Princeton under his advisor John Wheeler. A key foundation here was the proposition that an electron never acted upon itself but only on other electrons. This means that there is no EM field – there is only a direct interaction between point electrons but now, not instantaneously but with a time delay. The useful idea of a classical EM field would only be retained as an auxiliary but not a fundamental concept. Since this view deliberately ignored the detailed reaction of any source electrons, he needed the radiating electron's own EM field to react back on the electron to generate a recoil and produce a local conservation of momentum. Like almost all his predecessors, including his hero, Paul Dirac, he still separated the actions of the EM field from the focus, which remained a **single** electron at one point in space and time. This problem is eliminated in the present theory that includes the explicit role of the remote source electrons and therefore eliminates the EM field concept completely. Wheeler suggested that in a fully absorbing universe all the absorbers could retransmit their excitations backwards in time to the original radiating source. Feynman then showed that the half-retarded and half-advanced combination of the EM field would provide exactly the same result as a radiative reaction due to the source electron emitting only retarded EM radiation. This work was eventually published after the war in their famous joint paper. [97]

Wheeler and Feynman's use of the average of the local advanced and retarded EM fields, involved equal contributions from all of the past **and** from **all of the future**. This meant that this theory could **not** use the Hamiltonian method (used every where else in QM), which describes a system based on velocity, not momentum, and is defined in terms of a global, unique single time. They were forced to adopt the Principle of **Least Action**, which views the entire process from beginning to end (the conceptual perspective also taken in the present theory). [98]

The original motive behind Feynman's thesis was to quantize the classical action-at-a-distance electrodynamics. This was the first step in his revolutionary space-time viewpoint (that had gone out of fashion with modern QM around 1925) but was not described publicly by Feynman [99] until 1948. This approach was inspired by Dirac's use of the Lagrangian in 1933 (Dirac also correctly pointed out that this method is much more fundamental than the Hamiltonian approach). [100]

It was this perspective that initially inspired Feynman to create his own quantum field theory. In general, the formulation of the EM field, when it is used to mediate the interaction between electrical point particles, can be represented mathematically by an infinite set of quantized harmonic oscillators across all of space and time. In trying to understand how two atoms in a simple molecule could attract each other via electrical forces, Fermi developed a toy model of two classical atoms coupled by an elastic spring and discovered that the terms in the combined Hamiltonian representing longitudinal fluctuations could be replaced by an instantaneous Coulomb interaction between the particles [101]. Feynman (following Fermi) saw that the combination of longitudinal and time-like oscillators could be used as a suitable model of the instantaneous Coulomb field between electrons while the transverse oscillators would then act like photons [102]. Feynman (like Schwinger) used the sophisticated mathematics of functionals to eliminate the co-ordinates of the oscillators thereby introducing a direct delayed EM interaction between particles. As Feynman emphasized, this whole approach was limited to non-relativistic systems. In 1951, Feynman admitted in a letter to Wheeler that the quantized version of this earlier theory could not account for "vacuum polarization" (the canonical explanation of QED corrections). Indeed, he went so far as renouncing his earlier starting point [103] and denied that: "*electrons act only on other electrons*". In other words, he had to re-introduce the self-acting EM field to create his own version of QED, thereby betraying his physical intuition that had proved so fruitful in the past. The present programme reverts to Feynman's original ideas: electrons do **not** interact with themselves and there is no such existent as the EM field. Feynman's thesis becomes a critical step in developing the new theory introduced here.

5.2.2 FEYNMAN'S RADIATION MODEL

Feynman sees Light as Particulate

Feynman was very confident that light is particulate [104] because of the discrete effects observed with photo-multipliers in low intensity situations: "*as the light gets dimmer, the clicks remain just as loud – there are just fewer of them*." Feynman's confidence in this interpretation failed to acknowledge that it is the observed EM interaction that is discrete but unobserved *transmissions* (photons) are an extra interpolation – in other words, a theory, not a fact. The basic flaw of all theories is that there may be several different ways to interpret a given set of experiments – it is only the facts that cannot be argued with – theories are always tentative (even this one!). Feynman followed the conventional view and imagined light to be an entity. He was very clear that QED studied the interactions between two **real** entities – light and electrons. Unfortunately, although he acknowledged that both 'objects' exhibited particulate (localized) and wave-like (periodic) properties he still chose to refer to both as 'particles' (that could be described by lines or 'tracks' moving through space), refusing to use the neologism *wavicles* that other scientists hide behind: however, Feynman's was a very idiosyncratic use [105] of the word *particle*.

Feynman fails to interpret Light

When describing partial reflection in terms of photons, Feynman had no problem reviving Newton's "fits of reflection and refraction", as modern quantum theory is completely probabilistic. Feynman admits he doesn't know how a photon "makes up its mind" to go through or reflect back from a transparent medium. He found himself wrestling with the famous problem of classical determinism where the same circumstances should produce the same results: describing identical photons hitting the same glass surface generating different results. Again, the photon idea as moving-object presents insuperable conceptual problems when additional layers of this glass are added together [106] to produce oscillating zero to reinforced reflections. Historically, after Newton, partial reflection was explained by viewing light as interfering waves but the wave theory had no explanation for the experimental results when very weak light was reflected into photomultipliers – this led to the bizarre wave-particle "**paradox**" of modern quantum theory. Feynman went onto to show how probabilities are calculated in QED using 'rotating arrows' while refusing to offer [107] an explanation of how photons "decide" to bounce back or go through.

Polarization

The two-valued nature of light has been interpreted since the introduction of the wave model in the early 18^{th} Century as evidence for oscillations in the two independent directions transverse to the propagation (longitudinal) direction of the wave otherwise known as polarization. This was given a mathematical description in Maxwell's model of the EM field. Feynman accepted Maxwell's mathematics and by second-quantizing the EM fields interpreted them as photons. Since he was trying to construct a theory that was compatible with Special Relativity he treated all three space directions and the time dimension in a covariant manner to generate four types of photons, noting that at large distances the longitudinal and temporal photons cancel each other out. Interestingly, he pointed out that at atomic distances virtual temporal photons are dominant. It is viewed here as very significant that photon polarizations remain unchanged [108] once emitted from an electric source.

5.2.3 FEYNMAN'S MATHEMATICAL MODEL

Actors & Actions

One of the major appeals of Feynman's version of QED is that it initially appears very simple with direct mappings between visualizable features and mathematical expressions (that turn out to be horrendously complicated!). The two principal actors are electrons and light, each moving (as per Newton) in a straight-line from point to point unless an electron occasionally emits or absorbs a photon. Feynman's revolutionary proposition was to assume that these two 'actors' could be imagined to be moving through space just like classical point particles – a view that had been rejected by Heisenberg and the modern QM theorists since 1925. Feynman retained the probability model of QM by calculating the probability amplitude corresponding to one of these particles reaching a given place at a given time, after it was **known** to be at another place at another time.

No Mechanism – No Understanding

The greatest weakness of Feynman's approach is that it is still only a phenomenological model – a powerful mathematical technique that provides **no** understanding. Indeed, his theory fails to advance our understanding beyond the rock that sank Newton's 'ship of light' – namely, a mechanism for explaining such basic phenomena as the partial reflection of light by glass, admitting [109] that this theory provides "*no satisfactory mechanism to describe even the simplest of optical phenomena*".

5.2.4 FEYNMAN DIAGRAMS

Feynman first introduced his now famous diagrams in 1948 and this visually appealing technique soon exploded across the American post-doctoral physics community with over 100 authors using this technique by 1955 when the first two textbooks were published [110], [111] that introduced this mathematical method to a wider audience. Feynman's integrals, like all field theories, required integrations to be carried out across <u>all of space</u> [112] with explicit use of the idea of 'virtual' particles. Freeman Dyson first met Feynman in 1947 when they were both at Cornell University. Dyson's own first paper in *The Physical Review* in 1949 [113] codified the rules for constructing Feynman Diagrams. Dyson's next paper [114] followed soon after and again preceded Feynman's own first paper [115 introducing the new diagrammatic techniques. Ironically, Feynman here focused on **free** electrons (but treated using quantum mechanics) interacting with an external, classical EM field [116]; indeed, Feynman (like his peers) continued to approach EM through **Maxwell's Equations**.

The lines in these diagrams corresponded to mathematical Green's functions that represented electrons 'propagating' their probability amplitudes across space. It was Feynman's next paper [117] that first introduced his version of QED, where the wave functions were subject to the technique known as '<u>second-quantization</u>' and so were treated as quantum fields. It was deeply disappointing for Feynman that the mathematical integrals that corresponded to these formal graphs (or diagrams) led to <u>infinite divergences</u>, even at second order when 'virtual' particles first appeared. Consequently, at this time Feynman himself viewed [118] them as "***meaningless***". Dyson's first QFT paper [113] focused on a single electron interacting only <u>once</u> with the external EM potential but interacting with <u>itself</u> via any number of virtual photon 'excitations'. Soon after, Dyson's S-matrix paper [114] extended this to the scattering of **two** remote electrons that were initially so far apart that they did not interact. Dyson's own approach was always to <u>derive</u> the diagrams from his perturbation expansion of the interactive Hamiltonian field densities, $\mathbf{H}_I[x]$ (see above). Feynman always preferred the particle view of electrons and tried repeatedly to eliminate fields [119] that were always [120] the basis for Dyson's approach. Interestingly, it was Feynman's own PhD supervisor (John Archibald Wheeler at Princeton), who introduced the particle scattering technique later called the S-matrix approach.

The most deeply disturbing feature of Feynman diagrams is their very intuitive appeal – it soon became apparent that many theoretical physicists came to <u>believe</u> that <u>each</u> of these diagrams corresponded to the actual behavior of electrons as they underwent interactions. As Dyson repeatedly [120] told his students: the diagrams were '**visual aids**' – helping relate to complex expressions in an infinite expansion of the series of terms resulting from using an exponential function of a Hamiltonian density as the generative function relating two states of an electron at different times. Indeed, Dyson rarely ever presented any of these types of 'graphs' (as he called them) in any of his lectures on QFT. These diagrams undoubtedly helped Feynman in his early development of QED when he would initially insist that they represented reality (to him!).

Ultimately, Feynman failed to solve the problem of divergences in QED as his virtual states could represent **any** momentum whatsoever, including <u>infinite</u> momentum, because electrons could approach each other infinitely closely – the 'rock' that has always 'sunk' interactions between point particles interacting via a potential that varies inversely with separation. The ultimate insult was that only the lowest order calculations, without any of the virtual particles, had any real significance.

Ironically, the Feynman diagram technique only really became popular when it was used for nuclear physics – first meson-nucleon interactions and then later for quantum chromodynamics (**QCD**) where the wavy lines represented gluons. The fact that photographs of particle trajectories obtained in bubble chambers resembled these theoretical diagrams was more than just psychologically helpful. However, no one using these techniques in strong interactions was prepared to admit that using perturbation techniques were not appropriate when the interaction parameter (or coupling 'constant') was much greater than unity, whereas for QED this value (α) was about 1/137. Even now, the Standard Model is no better at providing insight into the behavior of nuclei based on binding protons and neutrons together than Heisenberg's original exchange mechanism.

The real message conveyed by the story of Feynman diagrams is that any approach (such as Faraday's lines-of-force) that conveys information in a form that may be <u>easily visualized</u> will be more readily accepted as meaningful and (in the case of physicists) will be much more readily extended than a purely symbolic formulation. These lessons have been completely accepted in developing the present theory; in fact, no mathematics appears here until **after** the concepts have been developed.

5.3 PROBLEMS WITH THE QED MODEL

5.3.1 QED INFINITIES

Coulomb Contradictions

The standard formulation of QED is based on Hamiltonian models extrapolated from classical physics: a small set of electrons (usually one) is considered to be interacting with a variable number of photons (modeled as an infinite set of simple harmonic oscillators [89] representing the quantized version of Maxwell's EM fields or potentials). The classical EM Hamiltonian for 'pure radiation' involves only transverse electric and magnetic fields with no Coulomb interactions. The inclusion of the Coulomb force is equivalent to introducing longitudinal EM waves (see the Fermi discussion above). These longitudinal EM waves can be eliminated between electrons by a mathematical transformation but this modifies the so-called 'bare' electron operator **C** into its 'dressed' version $\mathfrak{C}$, which includes its own Coulomb field. However, as Dirac pointed out, this is then a non-relativistic formulation, as a moving electron is not surrounded by a spherically symmetric Coulomb field. Furthermore, this transformation introduces an **instantaneous** Coulomb interaction between all pairs of electrons. As well as this quantum 'relativistic' EM theory contradicting its own roots (special relativity), even second-order perturbation corrections generate infinite (divergent) integrals directly associated with the virtual electron-positron "vacuum polarization". This is a problem that traces its roots all the way back to Dirac's relativistic theory [79] of the electron.

Infinite Hamiltonian Density

Pauli had long suspected that quantum theories were satisfactory whenever a **finite** number of objects were being considered but failed when an infinite number of possibilities existed (as in Dirac's 'electron sea' or QFT's vacuum of virtual particles). Dyson's QED/S-Matrix paper in 1949 [114] stated the basic problem with all such field theories is that they all include the Hamiltonian density of field interactions at one space-time point and this is always infinite. Dyson also recognized that the electron/positron field must always act as a unity [121] and not as a combination of two separate fields. Similarly, Dyson believed that the EM field itself must act as a unity; and not be treated as one part representing photon emission and another independent part representing photon absorption. However, no physicist was prepared to challenge the idea of an **EM field**.

Interactions Everywhere

The failure to study the history of their own subject is best exemplified by the mathematicians who invented quantum field theory (QFT) and simply added quantization conditions to the first and most prototypical classical field theory – Maxwell's classical theory of the electromagnetic field. Maxwell's theory was constructed on the ontological view that there existed a real medium (the **æther**) pervading all of space, throughout all of time. It was therefore quite consistent for Maxwell then to propose that the possibility of EM action could occur everywhere, particularly as he always rejected the idea of the existence of particulate electrical charges. Thus, to Maxwell, every location throughout space experienced the existence of a real EM field. However, the discovery of particulate electricity (i.e. **electrons**) should have resulted in the rejection of field theory as a mathematical model of electricity but mathematicians do love their continuous, differential equations to model the world.

Self-Interacting Fields

The fundamental error lying at the heart of all field theories is the separation of the unified interaction that arises between two interacting objects into **two** separable and **independent** events. The emitting object is viewed as creating a field object that moves freely through space until it (accidentally) encounters an absorbing object that destroys the field excitation. This has resulted in the totally false idea that a single electron can interact with its **own** 'field'. This error is then compounded by the idea that the electron's mass and charge are due to its own 'self-interaction' when both of these concepts [121] are inherently two-body concepts. Ideas like 'bare' mass and charge [122] are not simply "unobservable" but "illogical, non-physical concepts". QED is constructed around these erroneous ideas by beginning with 'free' electrons and 'non-interacting' photons. Since the very idea of photons is central to the idea of interactions between electrons then the theory of QED is constructed upon [123] an **inherent contradiction**. Subsequent problems of 'renormalization' (where each 'self-energy' integral in the perturbation expansion is infinite) are only to be expected when the potential energy varies inversely with distance, while no smallest separation is proposed between the electron and its own self-field. Various mathematical 'schemes' [124] (such as 'finite cut-offs', 'regularizing the integrands', 'dimensional regularization', etc.) are simply futile attempts to save a drowning man who is wearing a lead suit. Bizarre new approaches, such as String Theory or Quantum Foam, are just the latest desperate efforts by mathematical physicists to fix up problems, which are inherent in all QFTs.

5.3.2 BREAKING RANKS

Pauli rejects QED 'tricks'

Helge Kragh (an eminent historian of 20th century physics and Dirac's first biographer) quoted [125] a part of Pauli's Nobel prize acceptance speech in 1946 on QED, reflecting Pauli's intense physical intuition: "*a correct theory of nature should neither lead to infinite zero point energies nor to infinite electric charge, ... it should not use mathematical tricks to subtract infinities or singularities*." Pauli was not unique amongst world-class physicists who could not stomach bad physics.

Dirac dissatisfied with QED

Although Dirac is viewed appropriately as 'the Godfather of QED', he was prepared to express his extreme dissatisfaction with all the theoretical efforts in this area, when he wrote as early as 1936: "*We may give up QED without regrets – in fact, on account of its extreme complexity, most physicists will be very glad to see the end of it.*" In 1938, he wrote again: "*A new physical idea is needed which should be intelligible both in the classical theory and quantum theory and our easiest path of approach is to keep within the confines of the classical theory*." Unfortunately, Dirac did not then attempt to change the Maxwell-Lorentz equations but only to seek a new interpretation of them. Finally, in 1977, at the age of 75, he wrote: "*I really spent my life trying to find better equations for QED, and so far without success, but I continue to work on it.*" Ultimately, he failed and wrote [126], without qualification, in 1982: "*One can conclude that the fundamental ideas of the existing theory [QFT] are wrong*."

Dirac loses Faith in Maxwell's Field Theory

As early as 1937, Dirac suspected that the problems of QFT were due to a fault in Maxwell's CEM but even then (as now) there existed too many physicists who could not give up the elegance [127] captured by Maxwell's Equations. Dirac's intuition about the Maxwell classical theory is reinforced in the present programme where the Maxwell theory was deeply analyzed and criticized [3] in the third paper. There it was shown that Maxwell's æther model can be given a modern electron interpretation if the inter-electron interactions are given a statistical interpretation. This is a further example of the problems that arise in theories that omit all references to the sources of interaction, leaving only source-less forces (or worse, just potentials) that then tempt the mathematician to introduce even more mathematical steps in moving away from reality.

Dirac summarizes the Problems

In 1958, Dirac listed the deep problems with his own theory of the electron in the 4th edition of his masterpiece on quantum mechanics [128]; these included:

1) The second quantized electron fields are always associated together with their own instantaneous Coulomb EM field.
2) The relativistic multi-electron Hamiltonian function contains a spatial form of the Coulomb interaction corresponding to an EM energy associated with the instantaneous propagation of inter-electron forces.
3) The vacuum state representing no photons, electrons or positrons is not stationary but continuously fluctuates over time.
4) The 'vacuum' state does not have a zero charge density even when there is no interaction with the EM field.
5) The transition probability for the spontaneous creation of electron-positron pairs with the emission of a photon is infinite.
6) Perturbation methods involving the relativistic wave equation must be invalid as the transition probabilities are infinite.
7) After acknowledging the 'tricks of renormalization', Dirac concludes his own theory [129] with the prophetic statement: "*These difficulties, being of a profound character, can be removed only by some drastic change in the foundations of the theory; probably, a change as drastic as the passage from Bohr's orbit theory to the present theory of quantum mechanics*."

Feynman embarrassed by Renormalization

In *QED*, Feynman [130] circled around the two key numerical parameters in his theory - the electron's ideal rest mass m^* and its ideal charge e^* (no interactions) and admits that these theoretical numbers have to be "*stuck into the formulas to make the answers come out right*". All attempts to calculate the observed (or 'real') electron's mass m and charge e lead to divergent integrals (numerical infinities). These infinite values are finally "*subtracted away*" through a process dignified by the name '**renormalization**' but which Feynman (more honestly, as is his style) calls a "*dippy process*" again admitting that "*having to resort to such hocus-pocus has prevented us from proving that the theory of quantum electrodynamics is mathematically self-consistent.*" He even goes so far, as to *"suspect that renormalization is **not** mathematically legitimate*." In a footnote, he adds that the problem may be due to assuming that two points cannot be infinitely close together (but this is the very essence of every local field theory). Even with this '**fix**' included, calculations of total event probabilities exceed unity – a physical impossibility that contradicts the very foundations of modern quantum mechanics!

Field Theories imply Infinities

The theory of QED actually suffers from the same type of infinities as classical electromagnetism because in both theories interactions are viewed as occurring continuously so that in any finite time interval there will be an **infinite** number of interactions between any two electrons. Only discrete time interactions (like the present theory) fit Feynman's simple diagrams, discrete summation without any further integration. In Feynman's model, there can be an infinite number of sequential interactions ('ladder' diagrams) occurring in any finite time interval between just two real electrons.

Renormalization in Retrospect

The subtraction of **infinite** quantities became the cornerstone of renormalization techniques. As shown above, the more honest physicists could not swallow this contradiction in the very usage of mathematics to represent the real world, which always remains **finite**. The heart of the problem is that QFTs have always remained **local** field theories where all the interactions between several fields occur at **exactly** one point in space over an infinitessimal time duration. The very nature of using field mathematics in such a highly localized manner to avoid the finite time differences between two remote real particles means that divergence difficulties are **inherent** to all QFTs. This situation has become formalized in the last fifty years, where **all** theories are formulated as field theories, so that the requirement that all such theories become renormalized has now become accepted orthodoxy. The ultimate consequence of this desperate attempt to retain QFTs is now seen in the frightfully expensive experiments at CERN searching for the **Higgs boson** – a mathematical scheme to explain why all real particles have real, fixed masses. This research programme will address the problem of real particle masses in a later paper.

The problems with QFTs that were 'addressed' by renormalization illustrate a disturbing trend in theoretical physics – the psychological commitment to hold onto well-established theories when the undeniable presence of major problems should generate a search for alternatives. Instead, '**fixes**' are invented to preserve the intellectual investment made by so many theorists.

Agreement with the Lamb Shift

The extraordinary agreement between the measurements and calculations of the Lamb shift in the spectrum of the hydrogen atom has bedazzled physicists into accepting an approach that is inherently **wrong**. However, the history of science shows that scientists will cling to any theory, no matter how illogical, until they have a better one. In the case of QED, this can be illustrated by the concluding comment made by Paul Teller in his review [131] of QFT: "*As a particularly ingenious method for extracting information, renormalization will always remain the exemplar of good physics*." No one would ever guess that this accolade was referring to a theory [132] with so many problems but then orthodoxy today still views QED as "the best example of a good theory" in physics; it is not surprising to discover that Teller is a mathematical physicist.

Mathematical Madness

The esoteric 4th order QED calculations performed at Columbia around 1950 illustrate the ultimate endpoint of mathematics for mathematics sake (or 'math madness') that has taken over physics in the last 50 years. Dense pages of mathematics were needed (and three years of work!) to add a digit in the fifth decimal place of the electron's magnetic moment compared to the 2nd order results [133] of Karplus and Kroll. The extreme difficulty of verifying these calculations, such as Charles Sommerfeld's correction of 'arithmetic errors' ten years later [134] has meant that these methods have become a 'faith-based' approach, where only the original authors have to be trusted to have correctly counted the number of angels on these quantum pinheads. This 'cryptic' approach has become acceptable in spite of the scientists' claim that their knowledge is based on transparent and reproducible procedures (the medieval scholastics must be cheering away).

Even this process can fail, as Feynman described in *QED*, where he describes two 'independent' teams comparing notes and thereby making the same mistake. At least some of these displaced mathematicians were convinced they were dealing with real pins (electrons) but whether these myriads of invisible angels ('virtual particles') had any reality was an entirely different matter. It is difficult to imagine how anyone can justify the extra twenty years of work needed to calculate the 6th order QED calculations but Feynman proudly described the gigantic 8th order calculations involving over 10,000 different diagrams [135] with a total of over 5 million integrals. It cannot be denied that this 'make work' project has resulted in dozens, if not hundreds, of new PhDs in mathematical physics but it should be very obvious that this has not resulted in one single iota of greater understanding into the nature of reality.

5.3.3 OTHER QED PROBLEMS

Radiation Damping

The ‘reaction force’ is the classical calculated result of viewing a single charged particle when it is subject to an accelerating ‘external’ force via an interaction ‘field’. This removal of the source of this interaction then requires the target particle to interact with its own radiation field. Due to the directional nature of this acceleration, the EM field is no longer symmetrical so in a QFT the forward-directed photons must now have higher energy than those emitted in the reverse direction. The net recoil of this set of surrounding photons is calculated to ‘generate’ a net reaction on the particle as the explanation of the so-called “radiation damping force”. How electrons accelerate without interacting with other electrons remains a mystery.

Problems with QED

Throughout [68] his popular exposition, Feynman admits that the price of being able to calculate accurately in QED is to give up several **common sense** notions about the nature of light. These bizarre new features include the idea that light can simultaneously reflect off all parts of a mirror, light traveling along every possible path imaginable other than in a straight line and at all speeds from zero to infinity, light spontaneously transforming into pairs of electrons – all of this, along with the idea that electrons will travel backwards through time. **This is a steep price for an extra digit of accuracy**!

Non-physical Virtual States

The intermediate states (virtual quanta) cannot represent real situations (hence the label ‘virtual’) and are simply an attempt to impose a realistic mapping on mathematical intermediaries. This is because the virtual electrons are not restricted to the ‘mass-shell’ (i.e. they can have any numerical value and are not limited to the electron’s real rest mass m) while the virtual photons are not restricted to traveling at constant light speed c). Both of these parameters may have all values from zero to infinity. Moreover, it has not even been demonstrated that the **S-matrix** itself is finite, as its integrals also appear divergent. Simple ‘virtual photons’ do have a reality in the present theory but “polarization of the vacuum” (corresponding to complex virtual photons) has no role in the present theory. The core of Feynman’s problem with virtual photons is that he needed to expand his electron propagators across **all** intermediate electron states, everywhere in space and time, by treating them as a complete, orthonormal set using the simple representation of plane waves moving in all directions, not just as interactions between real electrons.

Cannot reverse Averaging

Since QED is based on quantizing the EM potentials that were derived from Maxwell’s Equations that were derived by statistical averaging from the integral, experimental results, it is not valid to try to reverse the averaging process to assume that these reflect the micro-reality; the conceptual foundations of QED are fundamentally and conceptually **flawed**.

Invisible Vacuum Effects

The mathematical view of the vacuum filled only with EM radiation was based on the ‘**equivalence**’ between a dynamical description of pure radiative fields and a system of harmonic oscillators, which not only did not interact with each other but always acted independently of one another. This correspondence is no more than adding a physical interpretation to a purely mathematical technique: in this case: Fourier transformations.

The quantum field model of the vacuum (i.e. QED), in the absence of all real particles in a local region of space, predicts the existence of zero-point field fluctuations, the temporary appearance and disappearance of pairs of complementary electrons (virtual particles), quantum states with negative energy and real particles with infinite mass and electric charge. All of these must be carefully removed by a series of mathematical techniques (‘renormalization’). However **none** of these has ever been observed experimentally and should never appear in any valid model of nature. This is another example of the fallacy of expecting every intermediate step in a mathematical exposition in physics to correspond to a state of the world.

This technique of creating physical explanations for purely mathematical steps re-appeared [136] in the so-called Casimir effect. This effect was attributed to the mathematical fiction of the polarization of Dirac’s ‘sea’ of virtual electron-positron pairs. It is much more likely to be due to the attractions between fluctuations of electron densities around the positive ions of the lattice on metal plates in close proximity.

5.3.4 RE-INTREPETING FEYNMAN'S QED

It must never be forgotten that Feynman's approach to QED, like ALL other modern quantum theories, is purely a mathematical scheme to generate some final numbers that might be then compared with the numbers obtained from experiment. Even these experimental numbers are inherently statistical since it is impossible to replicate the experimental situation exactly at the microscopic level, which is always an implicit requirement of using mathematics that implies a universal, timeless viewpoint. This motivation (comparing theoretical vs. experimental numbers) is incorporated into the very foundations of quantum mechanics. As a result, the mathematics is inherently statistical – the statistical nature of experiments is hidden in the requirement that the mathematical operators designed to correspond to 'observables' are chosen to have real eigenvalues that replicate the experimental spread of a series of observations made to compare these results. This does not mean that nature must be statistical at the microscopic level (Born's standard interpretation of the QM 'wave-function') but it does reflect the fact that all humans are massively larger than microscopic reality. Since all measurements, including optical ones, involve interactions between electrons, it is impossible for humans to conduct experiments on electrons without changing the reality of the microscopic situation involving those electrons before we intervened. This new view of quantum mechanics will be presented in the next paper in this series.

The major problem that has confronted quantum mechanics since its creation in 1925 is how to provide a physical interpretation of the mathematical machinery; after all, theoretical physicists are supposedly investigating the nature of **reality** and not just conducting exercises in abstract mathematics. The large number of alternative interpretations (over 10) of the meaning behind the mathematical machinery of QM indicates that this remains an embarrassing problem.

The present theory takes the view that any attempt to construct a **localized** theory of the microscopic world that includes electrons is doomed to create its own nemesis. This is because the EM interaction between pairs of remote electrons is intrinsically asynchronous: the action at one electron must always be at a different time than the reaction at the other electron. In other words, EM phenomena (which in this theory means all of physics) are inherently **non-local** in space and in time, so that the traditional **single-time**, view of the world (universally adopted by physicists since Newton) is **wrong**. Only a multi-time mathematical approach can ever hope to accurately model the two-time EM nature of the world. The consequence of adopting a local, one-time model is that the mathematics of **fields** must be used; this will force integrations to be taken over **all** of space and time (as in QM and QFT). These integrations are the source of the infinities that arise in these theories and do not reflect any real physical effects.

Indeed, the attempts to give interpretations to the various terms in Feynman's expansion of the core exponential function of the localized **Lagrangian** have led to the nonsense known as 'virtual particles'. Thus, the lowest order EM effect that is interpreted in QED as a 'photon transforming into a virtual electron pair' is actually an interference effect on the serial interaction between a source electron and its target electron by **two** real third-party electrons that always exist somewhere 'near'. One of these other electrons begins a short series of interactions with the source electron and the other third-party electron begins a similar short series of interactions with the target electron. These 'extraneous' EM interactions must be compatible in their durations and directions so that they conserve real momentum during these extra exchanges. There is nothing 'virtual' in these processes and certainly nothing that introduces any mathematical **infinities**. This view will be elaborated further in the next paper, where the focus will be the electron, not the 'photon'.

6. REMOTE ELECTRON INTERACTIONS

Newton's original physical intuition of interactions between point objects was simplified into a study of the single 'target' particle that was subject only to instantaneous **forces**. In classical mechanics, these were then transformed further into the spatial differentials of a new scalar concept of space alone – potential energy. Even within the study of electrodynamics, the **static**, spherically symmetric Coulomb potential retained its central role as the source of dynamical change. Maxwell's retention of this concept (through the Maxwell gauge: div $\underline{A} = 0$) ultimately resulted in the contortions of space and time associated with the so-called Lorentz transformation. The present theory restores **time** to center-stage and redirects attention away from single particles subject to 'free-floating' forces at one point in time, back to asynchronous **interactions** between **two** equally important remote, point particles, each participating in their own equally significant (but different) times. Every electron is subject to the **possibility** of an interaction [137] after a universal, invariant (local) interval of time – the chronon.

The present theory is based on Newton's views of invariant space and time; with particles moving through a passive space and inter-particle interactions occurring at only certain points in time. This traditional model rejects all views of both these fundamental 'background' concepts either mixing (through a change in an observer's motion) or becoming distorted due to large quantities of matter. Newton's mass particles are here seen as point **electrons** subject to mutual pair-wise interactions that manifest themselves as finite **impulses** at each participating electron. This theory is relational (or 'relative') because the interaction is only based on their relative spatial and temporal separations while the consequence (effect) of the impulse only depends on their relative positions and velocities. This research programme's views on the fundamental nature of Nature were first introduced in an earlier paper [138] and were elaborated further [139] in the previous paper.

This perspective is used in this section to create **realistic** models of the dynamic interactions between known, real particles (namely electrons that are foundational to this whole theory). The prior analysis of longitudinal interactions is now shown only to operate at limited physical separation between the two electrons due to the imposition of reasonable (quantum) constraints on the actions of the electrons. It is the changes in these mechanical actions of the electrons that constitute the EM interaction. The introduction of a small momentum exchange in the transverse direction is shown to apply at all physical separations and provides a readily understood mechanism for what has been viewed as "**transverse radiation**".

This chapter elaborates on the idea of remote, **asynchronous** interactions between electrons. It begins with a reiteration of the principal ontological properties of this electron model. It describes how certain mathematical creations (potentials) were introduced in the classical studies of electromagnetism to simplify the mathematical manipulations but were without any experimental justification. The emphasis here is on the key semantic category of **relationships** that focuses on interactions between two (otherwise) independent existents or **entities**, which have always been the focus of earlier studies of nature. The abolition of continuous interactions returns attention to Newton's original conceptual innovation: the **impulse**. The other challenge to conventionality is the abolition of the assumption of arithmetic addition of forces; instead, the key idea of **saturation** is proposed that ensures that any single interaction **never** involves more than one other remote electron.

The repeated **set** of interactions between **one** pair of remote electrons is now viewed here as the reality lying behind Einstein's mysterious concept of the 'quantum of light' or ***photon***. This has the ray-like effects of a particle while exhibiting periodic variations that are usually associated with the mathematical model of a continuously varying wave.

It was his mathematical intuition that forced Planck to pay attention to the ancient concept of **action** when he tried to model the phenomenon of Black Body radiation. His attempts at curve fitting forced him to quantize this exchange of action. A similar approach is used here to quantize both the exchange of dynamical and kinetic action across the interaction; both electrons now contributing equally to the total changes in action across a single interaction.

The majority of this chapter (§6.2.5) is dedicated to finding an analytic solution to the problem of two-electron **scattering** that respects the full, asynchronous interaction between them. This is a problem that has resisted all earlier attempts, using either Maxwell's theory or quantized versions (QED). Several attempts were made using this theory that failed to satisfy all the constraints developed herein but eventually a pair of trajectories was discovered that provided a comprehensive solution.

6.1 DISCRETE ELECTRON INTERACTIONS

6.1.1 THE ELECTRON INTERACTION MODEL

The Interaction Model

The four principal features (fundamental hypotheses) of the new EM model [140] are summarized below.

1) The world consists only of point electrons, whose existence is eternal.
2) Electrons only interact cyclically through an asynchronous exchange of action.
3) The interaction may only occur at either an electron's 'send' or 'receive' phase-point.
4) Each interaction is unique (saturated) – limited to one pair of electrons per interaction.

Asynchronous Interactions

An earlier paper [3] in this series demonstrated that a continuous model of interactions is not possible when instantaneous interactions are replaced by interactions involving **finite** delays that can only occur when the inertial point particles must be on each other's 'interaction cone'. Field theories bypass this constraint by using 'mass-less' fields involving one global time.

This new theory replaces both the continuous concepts of force and spatially dependent potentials (introduced by LaGrange) with the concept of discrete **impulses** acting only between **pairs** of point particles at two different times, with a magnitude that depends only on their temporal difference. The introduction of dynamic action restores the central role of time as the principal agent of change in the world. This was lost when kinetic action (based on kinetic energy) was the only feature of the Least Action approach. This radical, discrete approach re-emphasized the need for understanding mechanical action and the effective use of (equivalent) discrete equations of motion and the restoration of real particle trajectories when studying the behavior of matter at microscopic scales: this provides the bridge to **Feynman**'s view [99] of space-time histories.

Universal Durations

It is not sufficient to introduce a finite propagation time into a system to generate complexity, for each system component needs a 'natural' cycle time. This quantization of temporal duration allows the effect of arrival time on phenomena (i.e. the **phase** of the interaction) to become significant. Without this new opportunity to co-ordinate their actions together, it is very difficult to imagine how any system could achieve **complexity** or **stability**. For electrons, this ability to synchronize their activity determines which electrons will interact together. This is the major implication of the saturation hypothesis.

Interaction Saturation

The UET representation of the interaction between two electrons uses the fundamental electron differences: $T = t_1 - t_2$ and $\underline{S}[T] = \underline{x}_1[t_1] - \underline{x}_2[t_2]$ and their related natural vector derivative $\mathbf{V}^*[T] = d/dT[\mathbf{S}[T]]$; all of these are frame-invariant with respect to all forms of frame motion. There is no comparable set of invariant differences when three or more electrons are interacting together simultaneously, as in a model with one absorber (say, #1) and two emitters (#2 and #3). It therefore appears reasonable to hypothesize that the fundamental electron interaction in nature is always **pair-wise**, and **saturated**; i.e. at any instant t_1 when electron #1 is interacting there is only one other electron #2 that will interact with it at t_2.

6.1.2 ASYNCHRONOUS EM IMPULSES

No Forces or Potentials

The choice of saturated interactions acting **cyclically** between electrons in UET means that even two electrons do not always and continuously interact as they change their relative position – this means that there are no "conservative" forces. This eliminates the associated idea of potential energy of position $U[\underline{x}]$ which, intrinsically, exhibits no time dependency or any sensitivity to the history of each electron. The concept of potential energy at a point in space must be viewed as no more than a mathematical manipulation of the concept of a continuously varying force field (the spatial derivative of the space integral from infinity). As such, this concept is excluded from any consideration in the present theory where it would vary along velocity segments between impulse events. The concept of 'potential energy' now becomes only a time-averaged many-body effect that is used to calculate the effects on the 'target' electron moving incrementally through space produced by many source electrons that **could** interact with it at any time; i.e. a mathematical '**trick**' (or fictional construct).
The linear addition of potentials, at the same instant, is also a first order approximation of a serial process on a timescale far too small for experimental discrimination. As an analog, this may be thought of as everyone shouting at once at a party (with everyone hearing the resultant hubbub). The present view of synchronized, pair-wise interactions can then be thought of as

blowing kisses between two friends to signify their mutual attraction (or raspberries, if they are mutually repelled). The new theory reflects a higher level or consensual form of agreement, not random chaos. There appears to be several isomorphisms between the idea of an economic market and this new electron model. The principal market concepts include: humans, selling, buying, deals and price; these correspond to the following concepts: electrons, sending, receiving, interactions and amount of momentum exchanged.

The Impulse Alternative

The present theory proposes a new, discontinuous and asynchronous impulse form for the fundamental interaction between electrons. [141] This mechanism replaces Coulomb's continuous and instantaneous 'law' of electrostatics with a unified and universal dynamical basis for electromagnetism (EM). This programme fulfills Maxwell's original quest for extending Newtonian mechanics [142] to the phenomena of electricity and magnetism, for all relative speeds and distances – unifying both Special Relativity and Classical Mechanics. Furthermore, this new theory proposes a new, microscopic formulation for quantizing the dynamical and kinematical activity between non-local pairs of interacting electrons. This replaces Planck's arbitrary quantum of action that was introduced into mechanics and CEM to provide a discrete rule for 'explaining' atomic phenomena. These two radical proposals provide a new, revolutionary foundation for renewing progress in atomic, nuclear and particle physics while providing a physical explanation for the success of Bohr's original quantum theory of the atom.

Light Cone Condition

The parameter *c* defines the "light-cone" condition, introduced in the first paper in this series [143], where both electrons must be on each other's 'light-cone' whenever an interaction occurs; that is an electron (say, #1) at time t_1 located at $\underline{x}_1[t_1]$ may only interact with another electron (say, #2) at time t_2 located anywhere else in the universe at $\underline{x}_2[t_2]$ when:

$$(\underline{x}_1[t_1] - \underline{x}_2[t_2]) \bullet (\underline{x}_1[t_1] - \underline{x}_2[t_2]) \;=\; c^{\,2}\,(t_1 - t_2)^2 \;\text{ with } t_1 > t_2 \;\text{ or }\; t_1 < t_2\,.$$

Directionality

Einstein's original 'photon' hypothesis as an explanation of the photoelectric effect contained the important idea that the process of light emission must be **directional**. When this idea is combined with Poynting's result that EM energy and momentum are communicated orthogonally to the wave front then the mechanism of the EM interaction must involve spasmodic transfers of directed energy; i.e. momentum exchanges. Thus, any theory of interactions between electrons (the physical emitters and absorbers of any momentum exchange) must reflect this spatially directed characteristic; i.e. point-to-point between one emitting electron and one absorbing electron; spherically symmetric interactions are only time-averages.

Maximum Relative Speed

The UET model posits that the inter-electron interaction cannot occur when the relative, direct-line velocity exceeds light-speed. It is impossible for two electrons to have two consecutive interactions and still stay on each other's 'light-cone' when their relative velocity exceeds 'light-speed'. In Maxwell's EM theory this occurs when the magnetic part of the Lorentz force ($q\,(\underline{v} \wedge \underline{B}) / c$) equals the electric part ($q\,\underline{E}$); this occurs between two point charges when v equals *c* and B equals E.

Advanced and Retarded Impulses

The 'quantum' of interaction in the present theory is always a complementary pair of unit interactions because when two electrons are preparing to interact, one electron (say #1) is always at an earlier time than the other electron (say #2). The finite time difference between the act of 'sending' and the act of 'receiving' must always be a finite multiple of the unit time duration; in other words: $t_2 - t_1 \;=\; n\,\tau$ with $n > 0$ so that $t_2 \neq t_1$ thus $t_2 > t_1$. Therefore, if the first interaction begins with a 'retarded send' from electron #1 that is received later (after a time $n\,\tau$) as a 'retarded receive' by electron #2 (i.e. $S^-_1 : R^-_2$) then the complementary interaction must be an 'advanced send' from electron #2 that is received earlier as a 'advanced receive' by electron #1 (i.e. $S^+_2 : R^+_1$). This 'round-trip' set of interactions was described previously [144]. This pairing is why Wheeler and Feynman found they needed the average of retarded and advanced field solutions in their complete absorber model of EM; so the average impulse: $\Delta I \;=\; (\Delta I^- + \Delta I^+) / 2$. [97] When the relative velocities are very far apart (i.e. $|\,\underline{v}_1 - \underline{v}_2\,| \;\approx\; c$) then so-called relativistic effects become prominent. This 'double-exchange' is why Special Relativity theory needs to use the two-way definition for the <u>operational</u> determination of the speed of light using reflection from a remote mirror.

Feynman's earliest exposure to **advanced**, as well as retarded interactions (that he absorbed from his work with Wheeler) was retained in his final formulation of QED. He did not care if the virtual photons went forwards or backwards in time, essentially ignoring whether the electron emitted or absorbed such photons, characterizing them only as "exchanged". [145] In the present theory, such 'virtual photons' correspond to matched-pairs of interactions with electrons outside of the experimental region; they must occur in matched pairs to preserve the original momentum of the target electron within the experimental region (conservation of momentum being a cornerstone of all real particle dynamics).

One Interaction unifies Two Impulses

Although this model analyzes the interaction at each electron in terms of an equivalent impulse, it is important not to think of these two impulses as independent or real – they are **not** created at each electron and 'launched' across space with their own independent existence that happen to 'collide' somewhere between them. These two impulses are integral components of this single relationship: the electron interaction occurring between one pair of electrons at unique times for each electron. When a single interaction occurs between two electrons the identity of each electron has already been established – this is the heart of the present selection mechanism and contrasts completely with the anonymous '**broadcast**' mechanism of QFT.

This theory views inter**action** as the difference in action $\mathcal{A}_n$; an electron involved in an interaction changes its **rate** of action around its instant of interaction t_n, when it either emits or receives the corresponding impulse $\Delta \underline{\mathbf{I}}_n$ that defines the interaction. The change in action is the difference between the unit-action that includes the results of the interaction and the unit-action that **would** have happened **if** the transaction did **not** occur. These two unit-actions are both calculated from time $(t_n - \tau/2)$ up to $(t_n + \tau/2)$, where τ is the universal interval of time (the chronon); this is described more fully in the previous paper. [146] The digital electron model based on a single interaction between two remote electrons was also first described in an earlier section of this same paper [147] where the quantization of the interaction was also introduced. This action exchange is Galilean invariant because the presence of other (non-interacting) electrons (defining a 'reference frame') is irrelevant.

The view taken here is that of the 'unobserved' world; this is Kant's *noumena* (or 'things-in-themselves'). It is a description of the micro-world when 'left to itself'. The act of human observation is an additional (third-party) interaction that always disrupts this natural world. The next paper will develop a new theory of quantum mechanics that incorporates the effects of human measurements as disturbances on this world.

6.2 TWO ELECTRON REMOTE INTERACTIONS

The central fact of the modern view of electricity is that it is grounded in the interactions between discrete exemplars of electricity, known as electrons. With very few exceptions, the vast majority of these interactions (as observed by humans) occur between **negatively** charged electrons at distances greatly exceeding the size of atoms (about 10^{-8} cm). All of these interactions are separated in time between the emission and absorption of the exchanges of momentum – this separation is characterized by the universal constant, known as the speed of light (see §2.2.4) and always represented by the symbol *c*. The classical theory of EM 'smooths out' the actual discreteness (or graininess) of the world and **approximates** it with a model of a continuous medium of incompressible, electric fluid. The finite time differences between interactions are also replaced with smooth, mathematical functions that are defined everywhere across space and all evaluated at **one**, single time. The present theory will retain the physical discreteness of the electrons and the finite time differences across the interactions and will only introduce 'smoothness' in any final, mathematical approximations. The new theory of EM radiation analyzed here will continue to make the '**far approximation**' in that the spatial extent of the variations in the positions of the source electrons over time will be much smaller than the distance separating these electrons from any 'target' electrons that may interact with them. Situations involving much closer separations (particularly those involving separations at atomic or even nuclear distances) will be postponed for subsequent papers.

6.2.1 THE EXTENDED INTERACTION SET

Normally, energetic electrons localized in space ("EM sources") may interact in all directions of space around the source. All points on a set of discrete imaginary spheres, centered on a source electron, are equally possible interaction points when occupied by an electron that is at a suitable point in its interaction cycle (see §6.3.5). Spherical EM waves may therefore be viewed as the mathematical equivalent of the dual of these 'rays' of interaction possibilities. When a source electron at one of its emission times selects a remote partner electron, the two electrons will exchange one unit of momentum, always here designated by $\Delta \mathbf{I}_0$. Since the separation is assumed here to greatly exceed the width of a typical atom this involves the speed quantum, designated *b* and defined as c / N_0, where N_0 is the maximum number of interactions two electrons may participate in consecutively [148]. This ray-like exchange of momentum (the quantum of interaction or impulse) was introduce in the previous paper [141] and is defined in terms of the electron's intrinsic, invariant inertial mass *m*, that is: $\Delta \mathbf{I}_0 = m\, b$.

Often, when two remote electrons have decided that they form an optimum pair to exchange a unit of momentum it is very common that these two will again form the next optimum pair. This exchange can be repeated for very many consecutive interactions, characterized by a large but finite number $\mathcal{N}_P$. It is this interaction **set** between a pair of remote electrons that is now viewed here as the reality lying behind Einstein's mysterious concept of the 'quantum of light' or ***photon***. As was analyzed in an earlier paper [149] this set of interactions across space must all occur in the same direction $\underline{\hat{e}}$ defined by the separation between each pair of spatial locations at the time of each event pair, i.e. $\underline{\hat{e}} \equiv \underline{S}_n / S_n$ where $\underline{S}_n = \underline{x}'[t'_n] - \underline{x}[t_n]$ for all consecutive interaction events [n = 1, 2, … $\mathcal{N}_P$]. In actuality, this result strictly only applies when the interaction impulses are purely longitudinal (parallel to the 3D separation vector $\underline{S}_n$), in a later section (see §6.3.4) this condition will be relaxed for transverse impulses.

If the source electron moves periodically (with a period T_S) or changes its energy in a time duration of $T_S / 2$ then the source is characterized by a frequency *f* defined as: $f \equiv 1 / T_S$. The partner electron responds to these changes in the motion of the source electron at exactly the same rate over time; since these variations must be detected by the partner electron 'on the wave front' (i.e. after a finite time delay) then a spatial parameter referred to (for historical reasons) as the 'wavelength' λ can also be defined: $\lambda \equiv c\, T_S = c / f$. A radial frequency ω and wave-number κ are often useful: $\omega \equiv 2\pi f$ and $\kappa \equiv 2\pi / \lambda$. In completing one cycle, the two remote electrons will interact N_S times but it cannot be assumed that these occur evenly spaced across time; in fact, the only requirement is that the sum of the time intervals Δt_n between each of these events equals the cyclic time duration, i.e. $\Delta t_1 + \Delta t_2 + \ldots + \Delta t_{N_S} = T_S$. When the source fluctuations are periodic and the total exchange count $\mathcal{N}_P$ exceeds the number of interactions per cycle (N_S) then there will be a total of N_C fluctuations over the complete set of interactions (called a **pulse**) that extend over a total time duration $\mathcal{T}_P$.

$$\therefore\ \mathcal{T}_P = N_C\, T_S \quad \& \quad \mathcal{N}_P = N_C\, N_S$$

In the case of natural yellow sodium light, the source frequency is almost 5×10^{14} or $T_S \approx 2 \times 10^{-15}$ seconds; experiments indicate that $\mathcal{T}_P \approx 10^{-9}$ seconds so that the typical number of cycles (N_C) in a radiation exchange is about a million or so.

Pulses

In analyzing the dispersion effects of a diffraction grating on a short pulse of light, even the authors of the Encyclopedia Britannica article on light are forced to admit: "*it is unnatural to attribute any periodic quality to a single pulse ... but any finite pulse may be analyzed mathematically into an integral compound of* ***all*** *wavelengths. ... So that the analysis of light in terms of wavelengths is chiefly a matter of mathematical convenience*." [150] The emphasis **here** is always on **time**.

This set of interactions is equivalent to the generation of the classical equivalent of a single EM 'pulse' of duration T_P. Such pulses when generated by natural (e.g. atomic) sources often last for a billionth of a second – incredibly short on the scale of human sensibility but long in terms of the temporal quantum, where a chronon has a duration [151] of about 10^{-23} seconds.

The Fourier transform (in terms of frequencies f) of such a square-wave pulse is equivalent to an infinite set of frequency sine waves (diminished by the frequency), known as the **sinc** function and defined as: $\text{sinc}[f] \equiv \sin[\pi f] / \pi f$. In fact, this must be treated as a **discrete** Fourier transformation as the interactions [152] cannot occur continuously. This 'pulse of pulses' can be represented (mathematically) by a discrete set of sine waves whose number is also effectively finite due to the rapid fall-off of the amplitudes at higher frequencies. This is illustrated in the following diagrams.

Fig. 1 Set of Impulses over Time

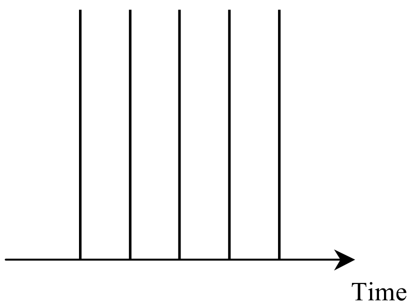
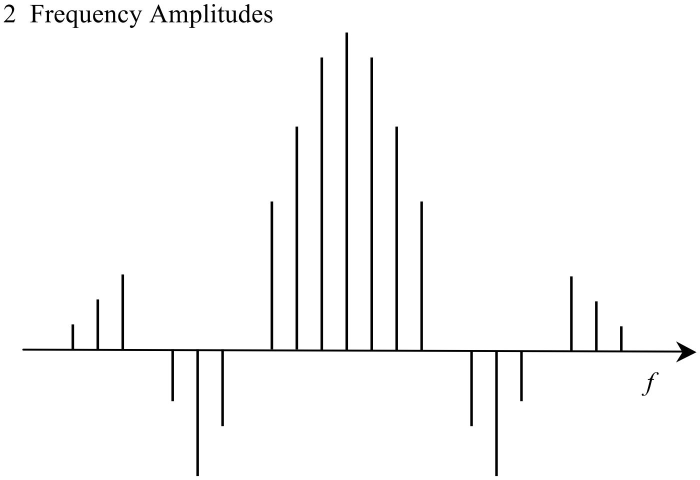


Fig. 2 Frequency Amplitudes



This view illustrates, in a nutshell, the problem of using continuous mathematical functions to represent the discreteness inherent in the interactions of the micro-world. In the present theory, time is still assumed to evolve continuously (both smoothly and without gaps) so that the location of a moving electron changes continuously from one point in space to another over time; each electron therefore **exists** only at one unique position in space $\underline{x}$ at any instant in time t so that it may be represented mathematically by a triplet of continuous functions $\underline{x}[t]$. In the absence of interactions during a finite time interval, the electron's motion is rectilinear during this interval, as Newton proposed for all free inertial particles. The very essence of the quantum world is that interactions between electrons are no longer assumed to be continuous (the central assumption of both classical and quantum mechanics) but only occur after discrete intervals of time. Again, in contrast to the simplifying assumptions of mathematical analysis, these time intervals Δt_n are not even equal for all electrons at all times but vary according to context. The principal determinant is the universal requirement to maintain the quantization of action both at the time of interaction (dynamic action) and between interaction events (kinematic action). These constraints mean that the electron's velocity no longer changes smoothly and continuously but changes by finite (discrete) amounts whenever an interaction event occurs. This means that an electron's velocity (or momentum) cannot be represented (as it always has been) by a continuous vector function of time $\underline{v}[t]$ but only by a discrete **set** of 3D vectors $[\underline{v}_n]$ at the event times t_n. When developing the modern theory of quantum mechanics, mathematicians naturally assumed the validity of continuity in their representation of the mechanics of the micro-world, so they assumed that the mathematical machinery of continuous Fourier transforms would be still be appropriate but this implied a continuous spectrum of frequencies. Unfortunately, experimental physicists (and Niels Bohr) had already shown that the quantum world of atoms is characterized by discrete frequencies. The various formulations of quantum mechanics around 1925 were just different mathematical schemes to introduce the quantization of kinematical action while preserving the continuum view of the electron's velocity – the need to abandon mathematical continuity was too great a price to be considered. This critical analysis will be picked up again in the next paper when a comprehensive theory of quantum **measurement** will be presented only in terms of discrete concepts.

6.2.2 THE COMPLETE EM INTERACTION

Electron Activity

The central importance of the concept of action $\mathcal{A}$ in electron dynamics was emphasized in the fourth section of the previous paper [146]. However, it was shown even in the first paper [153] that this was only the scalar component of the activity NV. It was also in the previous paper that the concept of digital quantization was introduced into the discrete electron interaction model [154]. The key result taken from there is that *each time two electrons interact they exchange one quantum of activity*. The definition of the single particle's **Activity** natural vector $\mathbf{R}_\eta$ at any of the discrete time marks t_η arises simply from the product of its DNV position $\mathbf{X}_\eta$ and momentum $\mathbf{P}_\eta$. ('Activity' may then be seen as the invariant 4D extension of action.)

$$\text{Digital Electron Activity} \quad \mathbf{R}_\eta \equiv i\,\mathbf{X}[t_\eta]\,\mathbf{P}[t_\eta] = i\,m\,\mathbf{X}_\eta\,\mathbf{V}_\eta^* \equiv i\,\text{Ɍ}_\eta\,\mathbf{I_0} + \underline{R}_\eta \bullet \underline{\mathbf{I}}$$

$$\text{Where:} \quad \text{Ɍ}_\eta = m\,(c^2\,t_\eta - \underline{X}_\eta \bullet \underline{V}_\eta) \quad \& \quad \underline{R}_\eta = \underline{\mathbf{R}}_\eta + i\,\underline{\mathscr{R}}_\eta \quad \text{with} \quad \underline{\mathbf{R}}_\eta = m\,c\,(\underline{X}_\eta - \underline{V}_\eta\,t_\eta) \quad \& \quad \underline{\mathscr{R}}_\eta = m\,(\underline{X}_\eta \wedge \underline{V}_\eta)$$

The first paper also showed that the single particle's **Activity** natural vector is a single mathematical quantity combining the **four basic concepts** in Newtonian physics, namely: time t_η , space $\underline{X}_\eta$, velocity $\underline{V}_\eta$ and mass m ; it can be re-stated as the sum of the three most powerful (derived) concepts in classical mechanics: action $\mathcal{A}_\eta$, Galilean momentum $\underline{\mathcal{G}}_\eta$ (or linear momentum $\underline{P}_\eta$) and angular momentum $\underline{\mathcal{M}}_\eta$.

$$\mathbf{R}_\eta \equiv i\,\mathcal{A}_\eta\,\mathbf{I_0} + \underline{\mathcal{G}}_\eta \bullet \underline{\mathbf{I}} + i\,\underline{\mathcal{M}}_\eta \bullet \underline{\mathbf{I}} \qquad \text{where} \quad \mathcal{A}_\eta = \text{Ɍ}_\eta \quad \& \quad \underline{\mathcal{G}}_\eta = \underline{\mathbf{R}}_\eta \quad \& \quad \underline{\mathcal{M}}_\eta = \underline{\mathscr{R}}_\eta$$

$$\text{or} \quad \mathcal{A}_\eta = (m\,c^2\,t_\eta - \underline{X}_\eta \bullet \underline{P}_\eta) \quad \& \quad \underline{\mathcal{G}}_\eta = c\,(m\,\underline{X}_\eta - \underline{P}_\eta\,t_\eta) \quad \& \quad \underline{\mathcal{M}}_\eta = \underline{X}_\eta \wedge \underline{P}_\eta$$

It was also in paper V that interaction was first viewed as activity exchange between two interacting particles – this required the introduction of a new difference operator $\boldsymbol{\delta}_0$ to quantify the effects induced by the interaction. The $\boldsymbol{\delta}_0$ operator computes the difference between any dynamical variable $\mathbf{A}$ that has been subject to one single interaction and the value $\mathbf{A}_0$ it **would** have had should there have been **no** interaction.

$$\text{Definition:} \quad \textbf{Impact Operator} \quad \boldsymbol{\delta}_0\mathbf{A} \equiv \mathbf{A} - \mathbf{A}_0$$

For example, a point particle has kinetic energy $\mathcal{K}_n$ when it is moving just before time t_{n+1} and it would preserve this value afterwards if there were no interaction but any interaction at time t_{n+1} would change its kinetic action to $\mathcal{K}_{n+1}$ leading to:

$$\boldsymbol{\delta}_0[\mathcal{K}_n] \equiv \mathcal{K}_{n+1} - \mathcal{K}_n = \Delta\mathcal{K}_n = \tfrac{1}{2}\,m\,(\underline{u}_{n+1} \bullet \underline{u}_{n+1} - \underline{u}_n \bullet \underline{u}_n) = \tfrac{1}{2}\,m\,(\underline{u}_{n+1} + \underline{u}_n) \bullet \Delta\underline{u}_n = \tfrac{1}{2}\,(\underline{u}_{n+1} + \underline{u}_n) \bullet \Delta\underline{\mathbf{I}}_{n+1} \neq 0$$

The principal time interval of interest in electron dynamics (referred to as the '*prime interval*') is defined from the moment just before any one interaction node ($t_\eta = t_{n+1}$) and extending right up to just before the next interaction node ($t_{\eta'} = t_{n+2}$). This includes exactly one and only one interaction but also includes the full resulting duration (Δt_n) after this one interaction. This temporal duration was used [155] to define the Interaction-Difference operator, designated by Δ_I and defined as:

$$\Delta_I\,A[t_n] \equiv A[t_{n+1} - \delta t] - A[t_n - \delta t]$$

These two linear operators may be combined to form the **Interval-Difference** operator: $\Delta_I{}^*A[t_n] \equiv \boldsymbol{\delta}_0\,\Delta_I\,A[t_n]$

The impact of a single interaction on the motion of an electron is entirely focused at the interaction point, say at $[t_{n+1} ; \underline{x}_{n+1}]$, when the target electron instantaneously changes its longitudinal velocity from $\underline{u}_n$ to $\underline{u}_{n+1}$ (that is, electron #1 receives from its other partner, electron #2, a non-zero impulse $\Delta\underline{\mathbf{I}}_{n+1} = m\,\Delta\underline{u}_n$). A more useful measure of change in activity looks only at the instantaneous change at an interaction node $\Diamond\mathbf{R}[t_n]$ since: $\Diamond[t_n] = 0$ & $\Diamond[\underline{x}_n] = 0$ but $m\,\Diamond\underline{u}_n = m\,\Delta\underline{u}_n = \Delta\underline{\mathbf{I}}_{n+1}$

$$\Diamond\mathbf{R}_{n+1} = \mathbf{R}[t_{n+1} + \delta t] - \mathbf{R}[t_{n+1} - \delta t] = -\,i\,m\,(\underline{x}_{n+1} \bullet \Delta\underline{u}_n)\,\mathbf{I_0} - m\,c\,t_{n+1}\,\underline{\mathbf{I}} \bullet \Delta\underline{u}_n + i\,m\,(\underline{x}_{n+1} \wedge \Delta\underline{u}_n) \bullet \underline{\mathbf{I}}$$

One must remember any complete difference over time combines both **extended** and **point** differences [156] : $\boldsymbol{\Delta} = \underline{\boldsymbol{\Delta}} + \lozenge$

$$\boldsymbol{\Delta}_I \mathbf{R}_{n+1} = \mathbf{R}[t_{n+2} - \delta t] - \mathbf{R}[t_{n+1} - \delta t] = i\, \Delta_I \mathrm{R}_{n+1}\, \mathbf{I_0} + \Delta_I \underline{\mathrm{R}}_{n+1} \bullet \underline{\mathbf{I}} + i\, \Delta_I \mathscr{R}_{n+1} \bullet \underline{\mathbf{I}} = \underline{\boldsymbol{\Delta}}_I \mathbf{R}_{n+1} + \lozenge \mathbf{R}_{n+1}$$

$\therefore\ \Delta_I \mathrm{R}_{n+1} = m\, [\Delta t_{n+1}\, (c^2 - \underline{u}_{n+1} \bullet \underline{u}_{n+1}) - (\underline{x}_{n+1} \bullet \Delta \underline{u}_n)]$ & $\Delta_I \underline{\mathrm{R}}_{n+1} = -\, m\, c\, t_{n+1}\, \Delta \underline{u}_n$ & $\Delta_I \mathscr{R}_{n+1} = m\, (\underline{x}_{n+1} \wedge \Delta \underline{u}_n)$

This can be reformulated in terms of the impulse $\Delta \underline{\mathbf{I}}_{n+1}$ and the electron's kinetic and dynamic actions $\Delta \mathcal{A}^K_n$ and $\Delta \mathcal{A}^D_n$.

$$\therefore\ \Delta_I \mathrm{R}_{n+1} = [\, m\, c^2 \Delta t_{n+1} + \Delta \mathcal{A}^K_{n+1} + \Delta \mathcal{A}^D_{n+1}\,] \quad \& \quad \Delta_I \underline{\mathrm{R}}_{n+1} = -\, c\, t_{n+1}\, \Delta \underline{\mathbf{I}}_{n+1} \quad \& \quad \Delta_I \mathscr{R}_{n+1} = (\underline{x}_{n+1} \wedge \Delta \underline{\mathbf{I}}_{n+1})$$

Since prime-intervals are fixed: $\therefore\ \Delta_I{}^* \mathbf{R}_{n+1} = i\, \Delta_I{}^* \mathcal{A}_{n+1}\, \mathbf{I_0} + \lozenge \underline{\mathcal{G}}_{n+1} \bullet \underline{\mathbf{I}} + i\, \lozenge \underline{\mathcal{M}}_{n+1} \bullet \underline{\mathbf{I}}$ $\therefore\ \Delta_I{}^* \mathcal{A}_{n+1} = \Delta \mathcal{A}^K_{n+1} + \Delta \mathcal{A}^D_{n+1}$

Dynamic Change: $\therefore\ \lozenge \mathcal{A}_{n+1} = \Delta \mathcal{A}^D_{n+1} = -\, \underline{x}_{n+1} \bullet \Delta \underline{\mathbf{I}}_{n+1}$ & $\lozenge \underline{\mathcal{G}}_{n+1} = -\, c\, t_{n+1}\, \Delta \underline{\mathbf{I}}_{n+1}$ & $\lozenge \underline{\mathcal{M}}_{n+1} = \underline{x}_{n+1} \wedge \Delta \underline{\mathbf{I}}_{n+1}$

Kinematic Change: $\therefore\ \underline{\boldsymbol{\Delta}}^* \mathcal{A}_{n+1} = \Delta \mathcal{A}^K_{n+1} = -\, m\, (\underline{u}_{n+1} \bullet \underline{u}_{n+1} - \underline{u}_n \bullet \underline{u}_n)\, \Delta t_{n+1} = -\, 2\, \Delta \mathcal{K}_n\, \Delta t_{n+1} = -\, \Delta t_{n+1}\, (\underline{u}_{n+1} + \underline{u}_n) \bullet \Delta \underline{\mathbf{I}}_{n+1}$

Thus, all *change of activity in the prime interval* is proportional to the remote impulse ($\Delta \underline{\mathbf{I}}_{n+1}$) with all the dynamic changes occurring at the interaction instant of time (t_{n+1}) with the kinematic change extending over all of the subsequent interaction interval ($\Delta t_{n+1} = t_{n+2} - t_{n+1}$). Denoting the activity at the **source** particle by primed quantities, then each single interaction occurring at time t_n at the target electron and at time t'_n at the source electron defines the combined activities of the two electrons (or two-particle activity) across the spatial separation ($\underline{S}_n = \underline{x}_n - \underline{x}'_n$) and time separation ($T_n = t_n - t'_n$) :

Definition: **Two-Electron Activity** $\mathbf{B}_{12}[\underline{S}_n\, ;\, T_n] \equiv \mathbf{R}[1{:}\ \underline{x}_n\, ;\, t_n] + \mathbf{R}'[2{:}\ \underline{x}'_n\, ;\, t'_n] = \mathbf{B}_n$

As $\mathbf{V}_n \equiv i\, c\, \mathbf{I_0} + \underline{u}_n \bullet \underline{\mathbf{I}}$ $\therefore\ m\, \lozenge \mathbf{V}_n = m\, \lozenge \underline{u}_n \bullet \underline{\mathbf{I}} = m\, \Delta \underline{u}_{n-1} \bullet \underline{\mathbf{I}} = \Delta \underline{\mathbf{I}}_n \bullet \underline{\mathbf{I}} = -\, m\, \lozenge \mathbf{V}'_n \equiv \Delta \mathbf{I}_n = \Delta \mathbf{I}_n{}^*$ (Impulse pseudo-DNV).

$$\therefore\ \lozenge \mathbf{B}_n = \lozenge[\mathbf{R}_n + \mathbf{R}'_n] = i\, m\, \lozenge[\mathbf{X}_n\, \mathbf{V}_n{}^* + \mathbf{X}'_n\, \mathbf{V}'_n{}^*] = i\, m\, (\mathbf{X}_n\, \lozenge \mathbf{V}_n{}^* + \mathbf{X}'_n\, \lozenge \mathbf{V}'_n{}^*) = i\, (\mathbf{X}_n - \mathbf{X}'_n)\, \Delta \mathbf{I}_n{}^* = i\, \mathbf{S}_n\, \Delta \mathbf{I}_n$$

Since $\mathbf{S}_n \equiv i\, S_n\, \mathbf{I_0} + \underline{S}_n \bullet \underline{\mathbf{I}} = (i\, c\, \mathbf{I_0} + \underline{c}_n \bullet \underline{\mathbf{I}})\, T_n \equiv \mathbf{C}_n\, T_n$ as $S_n = c\, T_n$ & $\underline{S}_n = \underline{c}_n\, T_n$ & $\underline{c}_n \bullet \underline{c}_n = c^2$

$$\therefore\ \lozenge \mathbf{B}_n = i\, \lozenge \mathcal{A}_n\, \mathbf{I_0} + \lozenge \underline{\mathcal{G}}_n \bullet \underline{\mathbf{I}} + i\, \lozenge \underline{\mathcal{M}}_n \bullet \underline{\mathbf{I}} = -\, i\, (\underline{S}_n \bullet \Delta \underline{\mathbf{I}}_n)\, \mathbf{I_0} - S_n\, \Delta \underline{\mathbf{I}}_n \bullet \underline{\mathbf{I}} + i\, (\underline{S}_n \wedge \Delta \underline{\mathbf{I}}_n) \bullet \underline{\mathbf{I}}$$

The E/M impulse $\Delta \underline{\mathbf{I}}_n$ that changes the instantaneous velocity of the target electron ($\Delta \underline{\mathbf{I}}_n = m\, \lozenge \underline{u}_{n-1}$) has a magnitude $\Delta \mathbf{I}_n$ in the direction $\underline{\ddot{e}}_n$ and can always be decomposed into its longitudinal component $\Delta \underline{\mathbf{I}}^L_n$ (parallel to the separation vector $\underline{S}_n$ or light-vector $\underline{c}_n$) of magnitude $\Delta \mathbf{I}^L_n$ in the direction $\underline{\mathring{A}}_n$ (remember Ångstrom for light vector) and its transverse component $\Delta \underline{\mathbf{I}}^T_n$ (orthogonal to the separation vector $\underline{S}_n$) of magnitude $\Delta \mathbf{I}^T_n$ in the direction $\underline{\tilde{n}}$. (NB note differences in direction: $\underline{\ddot{e}}_n$ and $\underline{\tilde{n}}$).

$\therefore\ \Delta \underline{\mathbf{I}}_n \equiv \Delta \mathbf{I}_n\, \underline{\ddot{e}}_n = \Delta \underline{\mathbf{I}}^L_n + \Delta \underline{\mathbf{I}}^T_n = \Delta \mathbf{I}^L_n\, \underline{\mathring{A}}_n + \Delta \mathbf{I}^T_n\, \underline{\tilde{n}}$ where: $\underline{c}_n = c\, \underline{\mathring{A}}_n$ & and $\underline{\mathring{A}}_n \bullet \underline{\tilde{n}} = 0$ but $\underline{\mathring{A}}_n \bullet \underline{\ddot{e}}_n \Rightarrow 0$ as $n >> 1$

Let ψ_n define the angle between the E/M impulse $\Delta \underline{\mathbf{I}}_n$ and the separation vector $\underline{S}_n$ at time t_n; i.e. $\underline{S}_n \bullet \Delta \underline{\mathbf{I}}_n = S_n\, \Delta \mathbf{I}_n \cos[\psi_n]$

$\therefore\ \underline{S}_n \bullet \Delta \underline{\mathbf{I}}_n = S_n\, \underline{\mathring{A}}_n \bullet \Delta \underline{\mathbf{I}}_n = S_n\, \Delta \mathbf{I}^L_n = S_n\, \Delta \mathbf{I}_n \cos \psi_n$ $\therefore\ \Delta \mathbf{I}^L_n = \Delta \mathbf{I}_n \cos \psi_n$ $\therefore\ \Delta \mathbf{I}^L_n = (\underline{S}_n \bullet \Delta \underline{\mathbf{I}}_n) / S_n$ Let $\underline{\tilde{a}}_n \equiv \underline{\mathring{A}}_n \wedge \underline{\tilde{n}}$

$\therefore\ \underline{S}_n \wedge \Delta \underline{\mathbf{I}}_n = S_n\, \underline{\mathring{A}}_n \wedge \Delta \underline{\mathbf{I}}_n = S_n\, \Delta \mathbf{I}^T_n = \underline{\tilde{a}}_n\, S_n\, \Delta \mathbf{I}_n \sin \psi_n$ $\therefore\ \Delta \mathbf{I}^T_n = \Delta \mathbf{I}_n \sin \psi_n$ $\therefore\ \Delta \underline{\mathbf{I}}^T_n = (\underline{S}_n \wedge \Delta \underline{\mathbf{I}}_n) / S_n = \underline{\mathring{A}}_n \wedge \Delta \underline{\mathbf{I}}_n$

$\therefore\ \Delta \underline{\mathbf{I}}_n = \Delta \mathbf{I}_n\, (\, \underline{\mathring{A}}_n \cos \psi_n + \underline{\tilde{n}} \sin \psi_n\,)$ $\therefore\ \underline{\ddot{e}}_n = \underline{\mathring{A}}_n \cos \psi_n + \underline{\tilde{n}} \sin \psi_n$ $\therefore\ S_n\, \Delta \underline{\mathbf{I}}_n = (\underline{S}_n \bullet \Delta \underline{\mathbf{I}}_n)\, \underline{\mathring{A}}_n + (\underline{S}_n \wedge \Delta \underline{\mathbf{I}}_n)$

$\therefore\ \lozenge \mathbf{B}_n = -\, S_n\, \Delta \mathbf{I}_n\, (\, \hat{\mathbf{A}}_n \cos \psi_n + \tilde{\mathbf{A}}_n \sin \psi_n\,) = \lozenge \mathbf{B}^L_n + \lozenge \mathbf{B}^T_n$ where $\hat{\mathbf{A}}_n = i\, \mathbf{I_0} + \underline{\mathring{A}}_n \bullet \underline{\mathbf{I}}$ & $\tilde{\mathbf{A}}_n = (\underline{\tilde{n}} - i\, \underline{\tilde{a}}_n) \bullet \underline{\mathbf{I}}$

Here $\hat{\mathbf{A}}_n$ is the (zero modulus) unit Light-DNV, as: $\mathbf{C}_n = c\, \hat{\mathbf{A}}_n$ and $\tilde{\mathbf{A}}_n$ is its complementary pseudo-DNV (no scalar part).

Quantizing Electron Activity

The previous paper introduced the hypothesis [157] of quantizing the new, discrete form of the electromagnetic impulse $\Delta\underline{\mathbf{I}}_n$. The assumption made throughout that paper was that that the EM impulse was only longitudinal (i.e. parallel to the light vector or separation vector $\underline{S}_n$). The quantization rule adopted therein focused on the two forms of the change in the total action $\Delta_I{*}\mathcal{A}_n$ generated by each interaction between the two electrons, namely the instantaneous (or dynamic) action $\Delta\mathcal{A}^D{}_n$ and the extended (or kinematic) action $\Delta\mathcal{A}^K{}_n$. The *change over the prime interval* in each of these two components of the **combined** electron activity was proposed to correspond to Planck's quantum of action h so that the foundational quantization rule here remains:

$$\textbf{Quantization}:\ \Diamond\mathcal{A}_n = \Delta\mathcal{A}^D[1{:}\ t_n] + \Delta\mathcal{A}^D[2{:}\ t'_n] = -h \quad \& \quad \underline{\mathbf{\Delta}}{*}\mathcal{A}_n = \Delta\mathcal{A}^K[1{:}\ t_n] + \Delta\mathcal{A}^K[2{:}\ t'_n] = -h$$

$$\therefore\ \Diamond\mathcal{A}_n = -(\underline{x}_n - \underline{x}'_n)\bullet\Delta\underline{\mathbf{I}}_n = -\underline{S}_n\bullet\Delta\underline{\mathbf{I}}_n \quad \therefore\ S_n\,\Delta\mathbf{I}^L{}_n = S_n\,\Delta\mathbf{I}_n\cos\psi_n = h \quad \therefore\ -\underline{\mathbf{\Delta}}{*}\mathcal{A}_n = 2\,(\Delta\mathcal{K}_{n-1}\,\Delta t_n + \Delta\mathcal{K}'_{n-1}\,\Delta t'_n) = h$$

It seems reasonable to assume that each electron makes an **equal** contribution to this kinematic change. $\therefore\ 2\,\Delta\mathcal{K}_{n-1}\,\Delta t_n = h/2$

A similar division of contribution in the dynamic effects results in a similar proposal: $\Delta\mathcal{A}^D[1{:}\ t_n] = -h/2\ \therefore\ \underline{x}_n\bullet\Delta\underline{\mathbf{I}}_n = h/2$

Since a similar division must apply for the source electron, then: $\underline{x}'_n\bullet\Delta\underline{\mathbf{I}}_n = -h/2$ this implies that either $\underline{x}'_n = -\underline{x}_n$ or 3D.

Thus, the total change in action for each electron over its prime interval is exactly one quantum; i.e. $\mathbf{\Delta}_I{*}\mathcal{A}[1{:}\ t_n] = -h$

$$\therefore\ \Diamond\mathbf{B}_n = -S_n\,\Delta\mathbf{I}_n\cos\psi_n\,(\,\hat{\mathbf{\Lambda}}_n + \tilde{\mathbf{\Lambda}}_n\tan\psi_n\,) = h\,(\mathbf{C}_n/c + \tilde{\mathbf{\Lambda}}_n\tan\psi_n) = i\,\Diamond\mathcal{A}_n\,\mathbf{I_0} + \Diamond\underline{\mathcal{G}}_n\bullet\underline{\mathbf{I}} + i\,\Diamond\underline{\mathcal{M}}_n\bullet\underline{\mathbf{I}}$$

$$\therefore\ \Diamond\mathcal{A}_n = -h \quad \& \quad \Diamond\underline{\mathcal{G}}_n = -h\,(\underline{\mathring{A}}_n + \tan\psi_n\,\underline{\tilde{n}}) = -S_n\,\Delta\underline{\mathbf{I}}_n \quad \& \quad \Diamond\underline{\mathcal{M}}_n = -h\tan\psi_n\,(\underline{\mathring{A}}_n\wedge\underline{\tilde{n}}) = \underline{S}_n\wedge\Delta\underline{\mathbf{I}}_n$$

The Longitudinal EM Impulse

Thus only the change in action is independent of the separation interval while the transverse changes vary with the tangent of the angle ψ_n defined by the direction that the impulse $\Delta\underline{\mathbf{I}}_n$ makes with the spatial separation vector $\underline{S}_n$. The longitudinal part of the EM impulse $\Delta\mathbf{I}^L{}_n$ varies inversely with the magnitude of the separation interval between the electrons at the times S_n. In order to comply with the 'light-cone' constraint [see §6.1.2], this separation must be an exact multiple of the quantized unit of distance, referred to here as the '***luxon***' (or classical electron radius), where: $\Lambda_0 = e^2/mc^2$. In other words, the interaction is only defined **at** the interaction intervals: $S_n = \kappa\,\Lambda_0$ where κ is a positive integer; therefore, using the fine structure constant α:

$$\therefore\ \Delta\mathbf{I}^L{}_n = h/S_n \qquad \therefore\ \Delta\mathbf{I}^L{}_\kappa = h/\kappa\,\Lambda_0 = (2\pi/\alpha)\,m\,c/\kappa \quad \text{with} \quad \Lambda_0 = c\,\tau \approx 4*10^{-14}\ \text{cm}$$

But the EM impulse $\Delta\underline{\mathbf{I}}_n$ always causes a change in the electron's velocity $\underline{u}_n$ (i.e. $\Delta\underline{\mathbf{I}}_n = m\,\Delta\underline{u}_{n-1}$) and so the maximum change would result from the target electron moving from rest to light-speed c as a result of *one* single interaction; this can only occur when the electrons are at their minimum interaction separation S_0 (or separated by the minimum number of luxons, $\kappa_0\Lambda_0$).

$$\therefore\ \Delta\mathbf{I}^L{}_0 = h/S_0 = h/\kappa_0\,\Lambda_0 = m\,c\ \ \therefore\ S_0 = h/m\,c = (2\pi/\alpha)\,\Lambda_0 = \lambda_C\ \text{(Compton wavelength: } 3.86*10^{-11}\text{ cm)}\ \ \therefore\ \kappa_0 = 2\pi/\alpha \approx 860$$

In the previous paper [157], two distinct ranges for the EM impulse were proposed: the short-range (or 'near') and the long-range (or 'far'). The present analysis now provides the mechanism for combining these two ranges into a single, 'seamless' vector impulse that extends the prior 'near' form of the magnitude to all distances while explicitly including the directionality that characterizes the EM interaction to account for the **transverse** effects introduced here. The longitudinal component of the EM impulse ($\Delta\underline{\mathbf{I}}^L{}_n = \underline{\mathring{A}}_n\,h/S_n$) dominates in 'near' interactions when $\cos\psi_n \approx 1$ and $\sin\psi_n \approx 0$ (or $\psi_n \approx 0$) while in contrast the transverse component ($\Delta\underline{\mathbf{I}}^T{}_n = \underline{\tilde{n}}\tan\psi_n\,h/S_n$) dominates in 'far' interactions when $\cos\psi_n \approx 0$ and $\sin\psi_n \approx 1$ (or $\psi_n \approx \pi/2$). In the same section of the previous paper, the form of the 'far' impulse was proposed to be: $\Delta\mathbf{I}_0 = m\,b$ where the quantum of velocity b is the smallest change in velocity created by a single EM interaction between two remote electrons. This will be the range involved in macroscopic optical experiments where the target electrons are very far (many atomic diameters) from the source electrons. Historically, the **transverse** component was given the name: '**magnetic**' force – this will not be used here.

The Transverse EM Impulse

It is now proposed that this longitudinal component (i.e. h / S_n) applies *equally in all directions*, including the longitudinal situation, for all separations so that it now takes on the features of a 'scalar' component. It is also now proposed that the 'far' part of the impulse (i.e. *mb*) is **added** to any transverse component that is orthogonal to the longitudinal component but its range now covers all separations. The new proposal assumes that the 'far' component is due only to the digital ('relativistic') motion of the electron described in the previous paper [158], as such, it reflects the 4-way 'clicking' motion around the average (or longitudinal) direction of the electron, which occurs after every chronon τ. This motion implies that the electron reverses its transverse direction after every 2 chronons; it also implies that the remote, transverse impulse also reverses direction at the same rate. This introduces the digital electron's **natural** 'oscillation' frequency, $\underline{\omega_0 = 2\pi / 4\tau} = \pi / 2\tau$. This will now be incorporated into the final form of the transverse impulse, for all separations.

Hypothesis: **The Transverse Component of the EM Impulse** $\Delta \underline{\mathbf{I}}^T_n = \Delta \mathbf{I}^T_n \, \underline{\tilde{n}} = (h / S_n + m\, b \exp[i\, \omega_0\, \Delta t_n])\, \underline{\tilde{n}}$

The speed quantum b is defined in terms of the speed of light c and a number, referred to here as the **Compton Number**, N_0. This fundamental number is named after Arthur H. Compton (1892 - 1962), who studied electron scattering extensively, as this number scales the minimum separation distance λ_C to the distance $\mathcal{D}_0$ where the magnitude of the longitudinal impulse equals the magnitude of the transverse impulse; this '**crossover**' distance was shown previously [157] to be about one millimeter. For optical distances (say, greater than 10 cm, the longitudinal impulse is less than 1% of the transverse impulse that dominates increasingly with further separation distance.

$$b = c / N_0 \quad \& \quad \mathcal{D}_0 = N_0\, \lambda_C \quad \therefore\ m\, b = m\, c / N_0 = h / \mathcal{D}_0 \quad \text{where} \quad N_0 = 3\pi / 2\alpha^4 \approx 1.65 \times 10^9$$

$$\therefore\ \Delta \mathbf{I}^T_n = h \tan \psi_n / S_n = h / S_n + m\, b \ \therefore\ \tan \psi_n = 1 + S_n / \mathcal{D}_0 \ \therefore\ \psi_n \approx \pi/4 \ (\text{when } S_n << \mathcal{D}_0) \ \&\ \psi_n \approx \pi/2 \ (\text{when } S_n >> \mathcal{D}_0)$$

Thus, only the absolute spatial separation of the pair of interacting electrons at the two times of their interaction determines the magnitude and direction of the impulse each electron experiences.

Interaction Angle

When the two interacting electrons are far apart ($\underline{S}_n \approx \underline{S}_{n-1}$) and their relative velocities are relatively close ($\underline{V}_n \approx \underline{V}_{n-1} >> b$) then the next interaction event at $\underline{x}_{n+1}$ will be determined more by **inertial** effects rather than by latest changes induced by the previous interaction. It will be shown later (§6.2.4) that minimizing each interaction time is optimally achieved when the direction of the transverse interaction ($\underline{\tilde{n}}$) is parallel to the previous longitudinal velocity of the particle involved; $\underline{\hat{u}}_n$. This suggests that the transverse interaction direction is given by the formula.

$$\underline{\tilde{n}} = \underline{\mathring{A}}_n \wedge (\underline{\hat{u}}_n - \underline{\hat{u}}_{n-1})$$

Quantizing Angular Momentum

In the case of optical effects, the spatial separation is great enough that the 'far' approximation is always appropriate; i.e. the magnitude of each impulse is always '*mb*' when the impulse is almost completely orthogonal to the separation vector. The new form of the transverse impulse leads to an interesting result for the change in combined angular momentum of the two interacting electrons each time they commit to a single EM interaction.

$$\therefore\ \Diamond \underline{\mathcal{M}}_n = \underline{S}_n \wedge \Delta \underline{\mathbf{I}}_n = \underline{S}_n \wedge \Delta \underline{\mathbf{I}}^T_n = h\, (1 + \exp[i\, \omega_0\, \Delta t_n]\, mb\, S_n)\, \underline{\mathring{A}}_n \wedge \underline{\tilde{n}} = \Delta \mathcal{M}_n\, (\underline{\mathring{A}}_n \wedge \underline{\tilde{n}}) \ \therefore\ \Delta \mathcal{M}_n = h\, (1 + \exp[i\, \omega_0 \Delta t_n]\, S_n / \mathcal{D}_0)$$

Thus, at small atomic separations ($S_n << \mathcal{D}_0$), which corresponds to low principal quantum numbers, $\Delta\mathcal{M}_n = h$ (one unit of quantized angular momentum) but at very high quantum numbers or beyond, i.e. optical distances ($S_n >> \mathcal{D}_0$), $\Delta\mathcal{M}_n > h$. Fortunately, the exponential factor introduces a very high-speed oscillation (the Dirac '*Zitterbewegung*' [159]) that is too fast to measure and results in an average, measured value of zero over measurement times greatly exceeding a few chronons (or about 10^{-24} seconds). Thus, it is suggested that this change in angular momentum only occurs with 'near' interactions, so that the rule is proposed that:

$$\Diamond \underline{\mathcal{M}}_n = h\, (\underline{\mathring{A}}_n \wedge \underline{\tilde{n}}) \quad \text{when} \quad S_n << \mathcal{D}_0 \quad \text{and} \quad < \Diamond \underline{\mathcal{M}}_n > = 0 \quad \text{when} \quad S_n >> S_0$$

This makes changes in orbital angular momentum only an atomic phenomenon when: $\Delta\mathcal{M}_n = \pm h$; this rule has always been **confirmed** experimentally.

6.2.3 FAR INTERACTIONS AS TRANSVERSE IMPULSES

The implications of the introduction of **directionality** in the interaction between two electrons are very significant.

1. The crossover distance for EM interactions from 'near' to 'far' is at macroscopic distances ($\mathcal{D}_0$ is about 1 mm).

2. The 'near' quantum effects are not a linear extrapolation from macroscopic observations (Maxwell's Equations).

3. The impulses acting on 'far' electrons act overwhelmingly in a direction orthogonal to their line-of-centers.

Impulse Model is Comprehensive

The **Standard Model** of physics consists of twelve 'real' particles (or fermions divided into 3 families) that interact through three fundamental forces. These forces include the EM force that manifests its effects at atomic distances and greater, while stable nuclear particles are constrained by the **strong** force that acts only at nuclear distances. These are complemented by the **weak** force that also acts only at nuclear distances and was introduced to explain the extra-nuclear decay of neutrons. The **gravitational** force completes this quartet and is absurdly small in comparison with the other three – it only is manifest when gigantic numbers of electrons and nuclear particles aggregate together and cancel out all the other forces. All of the 3 standard forces are treated as mathematical fields that also appear as 12 interaction particles (or **bosons**); this whole mélange requires **19** arbitrary numerical constants to fit the theory to the experimental observations.

In contrast, the present model of EM consists of **only** one type of real particle (the electron) and **only** requires the impulse model of interactions between pairs of electrons that varies in intensity with separation; this replaces the 'zoo' of so-called fundamental particles with composites of positive and negative electrons. Even gravity in the present model is viewed as a very rare, remote and finely tuned pair of EM pair-wise interactions. All of these models will be presented in a later series of papers.

Maxwell's Model favors Radiation

The present research programme examined the evolution of the theory of Classical Electro-Magnetism (**CEM**) in the second paper in this series. There it was emphasized that Maxwell's theory was a mathematical transformation (into a differential form) of the integral formulation that summarized the **experimental** observations of macroscopic electrical circuits. It is this mapping that gives the Maxwell (actually Heaviside) Equations their universal validity when used to calculate macroscopic electrical and magnetic phenomena. It was also shown there that Maxwell's principal innovation was his introduction of the vector potential as a mathematical field that acted as the primary generator of so-called magnetic (actually motional) effects. Maxwell's physical model of the **æther** collapsed with the discovery of the electron but the EM equations were preserved when Hertz discovered the phenomenon of remote induction (more popularly known as EM radiation). CEM was salvaged when it was realized that Helmholtz's failed hydro-dynamical model of EM could be recast into a Maxwellian form by using the continuum approximation for electric charge density. The dramatic introduction of the quantum should have put an end to all of this continuous mathematical theorizing but instead it only resulted in the eventual introduction of quantized fields. The problems with this approach have been referred to continually throughout this series of papers that are founded on the discreteness of the electron – an experimental fact that must be the foundation of all future theorizing in electromagnetism. This was begun in the third paper where it was proposed that a **mesoscopic** (small-scale statistical) conduction model of electron interactions could be constructed that explained and described the macroscopic set of experimental observations.

Far Impulse Model favors Radiation

The vastly more powerful strength of the 'near' interaction means that these interactions will result in much larger kinetic energies so the intervals between interactions $\mathtt{T}_n$ will be very much smaller, implying that these events will occur much more frequently. Furthermore, very high-speed (or 'hot') electrons will cover more "chronon points" (i.e. those spatial points on light-cones where an interaction with other electrons is possible) in any given unit of time than a slower electron. However, should a 'far' interaction still occur then it will destroy the delicate balancing conditions that are often required to maintain a 'near' **system** (and energy conserving) equilibrium and it will then take several 'far' interactions before another 'near' event becomes possible again. Thus, the impulse model would expect very high-speed electrons to 'radiate' away their energy via interactions with remote electrons and more often (i.e. as higher frequency 'photons') than via local collisions.

6.2.4 THE GENERALIZED INTEGRITY CONDITION

Earlier Analyses

The realization that the inter-electron impulse has a **transverse** as well as longitudinal (line-of-centers) component means that the dynamics of two-electron systems must be modified. In all our earlier studies of such two-electron systems a purely one-dimensional analysis was considered adequate, this must now be revised to recognize its full three-dimensional nature.

The first analysis of a system of two similar charged electrons was half-jokingly referred to as '*The Terrible Twins*' [160]. This label was used because, although this is the simplest real EM system that might be imagined (particularly since the discovery of the electron over 100 years ago), its dynamics have embarrassingly never been solved analytically until now. Perhaps, this is why such a system is **never** discussed in modern texts on EM. The history of these earlier, failed attempts was summarized in the third paper in this series [161]. In the 1D model, the two electrons first approach each other when both are each moving at light speed (as seen from the **Historical** View – the God-like single-time perspective). As they interact, they both lose kinetic energy until they reach their minimum separation when both reverse direction and accelerate away from each other regaining their 'lost' kinetic energy until they again are moving at light-speed. In the **Interaction** View – the fully global two-time perspective at each electron, the interaction always spans a great distance and the relative, combined speed of the two electrons always remains constant (at light-speed *c*). This system was revisited in more detail in the fifth paper [162] to emphasize the symmetries in the Interaction View and incorporate 3D features of the Digital Model.

The final study of the '*Terrible Twins*' analyzed the dynamics of attractive scattering [162] when the two electrons have opposite electric charges. Again, this was limited to 'far' interactions with the motion limited to one spatial dimension. Two possible solutions were investigated but only the so-called 'parabolic' scattering model offered similar linear solutions to the repulsive scattering case. Again, in the Historical View the two particles are initially approaching each other at light-speed but over-shoot before starting to exchange impulses, stopping at $t = 0$ (at a great distance) before continuing to send impulses again until they cross paths one last time and continue off forever, each receding at light-speed. In all these models, the two particles are always on each other's 'light-cone' at all the times of their interactions; this results in every pair of interaction events defining a parallel set of rays (or "light-vectors") in 3D space. All of these analyses were based on the assumption that each impulse always exhibited the same magnitude ($\Delta\mathbf{I}_0 = mb$) and acted longitudinally at all times; here, b is the minimum change in electron speed and is equal to the speed **first** achieved after its change in direction. The 'lost' kinetic energy is not regained in full until the all of the 'rebound' interactions are complete (or when the two symmetric pairs of interactions have completed their interactions) but this would be invisible to a third (or measuring) electron that would be ignored throughout all of these interactions.

Complete 3D Analysis

These earlier analyses were constructed upon the implicit view that the two-electron interaction was purely longitudinal and this resulted in the velocity constraint called Space-Time Integrity Condition; this was developed in Paper III sections 6.3-4, this will now be generalized. Consider two consecutive interactions, labeled n and (n+1), between two electrons (of any charge). Each interaction consists of the exchange of momentum between the two particles that is described mathematically as the asynchronous 'receipt' of an impulse $\Delta\underline{\mathbf{I}}$ by electron #1 after the 'emission' (and reaction) of a matching impulse $\Delta\underline{\mathbf{I}}'$ by electron #2. The n^{th} impulse is emitted at $[\underline{x}'_n ; t'_n]$ and received at $[\underline{x}_n ; t_n]$, these two interaction events define the spatial and temporal separations: $\underline{X}_n \equiv \underline{x}_n - \underline{x}'_n$ and $T_n \equiv t_n - t'_n$ while the unit spatial separation vector $\underline{\mathring{A}}_n \equiv \underline{X}_n / |\underline{X}_n|$ defines the 'light-vector' $\underline{c}_n \equiv c\,\underline{\mathring{A}}_n$; thus, as these two events are on each other's light-cone: $\underline{X}_n = \underline{c}_n T_n$. Let: $\Delta t_n \equiv t_{n+1} - t_n$. Euclidean geometry allows two independent paths between $\underline{x}'_n$ and $\underline{x}_{n+1}$ while their spatial separation remains unchanged.

$$\therefore\ \underline{X}_{n+1} - \underline{X}_n = (\underline{x}_{n+1} - \underline{x}'_{n+1}) - (\underline{x}_n - \underline{x}'_n) = (\underline{x}_{n+1} - \underline{x}_n) - (\underline{x}'_{n+1} - \underline{x}'_n) \quad \therefore\ \underline{X}_{n+1} - \underline{X}_n = \Delta\underline{x}_n - \Delta\underline{x}'_n = \Delta\underline{X}_n$$

$$\therefore\ T_{n+1} - T_n = (t_{n+1} - t'_{n+1}) - (t_n - t'_n) = (t_{n+1} - t_n) - (t'_{n+1} - t'_n) \quad \therefore\ T_{n+1} - T_n = \Delta t_n - \Delta t'_n = \Delta T_n$$

$$\therefore\ \underline{X}_{n+1} = \underline{c}_{n+1} T_{n+1} = \underline{c}_{n+1} (T_n + \Delta t_n - \Delta t'_n) = \underline{X}_n + \Delta\underline{x}_n - \Delta\underline{x}'_n = \underline{c}_n T_n + \underline{u}_n \Delta t_n - \underline{u}'_n \Delta t'_n$$

This results in the ***G****eneralized* ***I****ntegrity* ***C****ondition* (**GIC**): $\quad (\underline{c}_{n+1} - \underline{c}_n)(t_n - t'_n) + (\underline{c}_{n+1} - \underline{u}_n)\Delta t_n = (\underline{c}_{n+1} - \underline{u}'_n)\Delta t'_n$

Alternatively, this may be formulated as: $\quad \Delta\underline{X}_n = \underline{c}_{n+1} \Delta T_n + T_n \Delta\underline{c}_n \qquad$ Obviously, if: $\Delta\underline{c}_n = 0$ then $\underline{c}_{n+1} = \underline{c}_n = \underline{c}$

Here, the longitudinal velocities are defined along their average trajectories: $\underline{u}_n \equiv \Delta\underline{x}_n / \Delta t_n$. The GIC also follows directly from the application of the **total** finite difference operator Δ on the 'light-cone' condition; i.e. $\Delta[\, \underline{X}_n \,] = \Delta[\, \underline{c}_n \, T_n \,]$.

The following diagram will illustrate the role of the directionality of the component impulses on the motion of the particles.

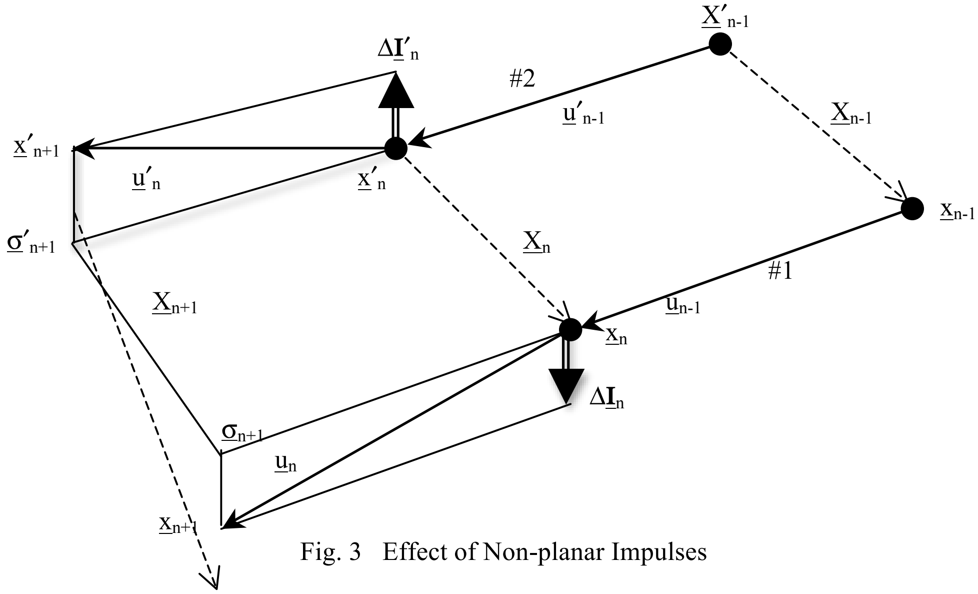


Fig. 3 Effect of Non-planar Impulses

Here, electron #1 would continue moving still with velocity $\underline{u}_{n-1}$ onto location $\underline{\sigma}_{n+1}$ at time t_{n+1} if the n^{th} interaction had **not** occurred; similarly for particle #2 moving at velocity $\underline{u}'_{n-1}$ would have reached $\underline{\sigma}'_{n+1}$ at time t'_{n+1}. For simplicity, let $\underline{u}_{n-1}$ and $\underline{u}'_{n-1}$ define the (x-y) plane, thus all the points $[\underline{x}_{n-1}\,,\ \underline{x}_n\,,\ \underline{\sigma}_{n+1}]$ and $[\underline{x}'_{n-1}\,,\ x'_n\,,\ \underline{\sigma}'_{n+1}]$ have no z-component. Now, since the impulse: $\Delta\underline{\mathbf{I}}_n = \Delta\underline{p}_n = m\,(\underline{u}_n - \underline{u}_{n-1})$ then $\underline{u}_n$ will remain in the (x-y) plane if $\Delta\underline{\mathbf{I}}_n$ has no z-component. This will be true if the EM impulse is purely longitudinal (i.e. $\Delta\underline{\mathbf{I}}_n = \Delta\underline{\mathbf{I}}_L$) or if the EM impulse contains a transverse component $\Delta\underline{\mathbf{I}}_T$ that is always constrained to be in the (x-y) plane as well (i.e. $\Delta\underline{\mathbf{I}}_n = \Delta\underline{\mathbf{I}}_L + \Delta\underline{\mathbf{I}}_T$). However, by definition, every light-vector $\underline{c}_n$ defines the direction between the two events constituting each interaction, so if the parallel condition: $\underline{c}_{n+1} = \underline{c}_n$ is imposed then the EM impulse must be purely longitudinal (i.e. $\Delta\underline{\mathbf{I}}_n = \Delta\underline{\mathbf{I}}_L = \Delta\mathbf{I}_n\,\underline{\mathring{A}}_n = \underline{c}_n\,\Delta\mathbf{I}_n / c$). This condition then eliminates the first term in the Generalized Integrity Condition (above), reducing it to the earlier Space-Time Integrity condition (STI).

$$\therefore\ (\underline{c}_{n+1} - \underline{u}_n)\,\Delta t_n = (\underline{c}_{n+1} - \underline{u}'_n)\,\Delta t'_n \quad \therefore\ \underline{c}_{n+1}\,(\Delta t_n - \Delta t'_n) = \underline{c}_{n+1}\,\Delta T_n = \Delta\underline{x}_n - \Delta\underline{x}'_n \quad \therefore\ \underline{c}_{n+1} = \Delta\underline{X}_n / \Delta T_n = \underline{X}_{n+1} / T_{n+1}$$

The 'twisting' impulse (when the transverse component is constrained to remain in the plane of the two input velocities) will not be investigated further here as this would result in too heavy a bias towards a two-dimensional world. A fully 3D world is much more likely if the transverse impulse $\Delta\underline{\mathbf{I}}_T$ is assumed to act orthogonally to the plane of the two input velocities. All experiments indicate that the EM interaction preserves linear momentum so the complementary impulse must occur in the opposite (spatial) direction (i.e. $\Delta\underline{\mathbf{I}}_n = -\Delta\underline{\mathbf{I}}'_n$); this introduces a **torque**-like effect on the motion of the two particles that effectively **rotates** the plane of their two input velocities as they become two output velocities.

Transverse Ambiguity

It was proposed earlier (§6.2.3) that the EM interaction between two electrons (the 'far radiation' interaction) consists overwhelmingly (when $S_n > \mathcal{D}_0$) of a small transverse component $\Delta\mathbf{I}_T$ that has a constant magnitude *mb*. This still requires the <u>direction</u> of this transverse component to be determined. Since this impulse is almost transverse, it must be orthogonal to the 'light-vector' or, equivalently, orthogonal to the 3D separation vector $\underline{X}_n$ defining the difference in the spatial locations of the two electrons at the times of their participation in the n^{th} interaction. Even this orthogonality constraint is insufficient to fully determine the direction of the transverse impulse, as it could be lie anywhere in the plane orthogonal to the light-vector. It will be necessary to find the rule that uniquely defines this direction $\underline{\ddot{e}}_n$ when electrons interact at 'far' distances. Thus, the transverse impulse vector $\underline{b}_n$ is defined by: $\Delta\underline{\mathbf{I}}_n \equiv m\,\underline{b}_n \equiv m\,b\,\underline{\ddot{e}}_n = -\Delta\underline{\mathbf{I}}'_n$ subject to: $\underline{c}_n \bullet \underline{\ddot{e}}_n = 0$.

Resolving the Transverse Directionality

Any 3D vector $\underline{V}$ may be decomposed into a part $\underline{U}$ parallel to another unit vector, say $\underline{\hat{e}}$, and a part $\underline{W}$ orthogonal to $\underline{\hat{e}}$ but also in the plane $\underline{\ddot{e}}$ defined by the vectors $\underline{\hat{e}}$ and $\underline{V}$. This is accomplished using the universal identity involving the triple-cross product:

$$\underline{A} \wedge (\underline{B} \wedge \underline{C}) = \underline{B}\,(\underline{A} \bullet \underline{C}) - \underline{C}\,(\underline{A} \bullet \underline{B}) \qquad \therefore\ \underline{\hat{e}} \wedge (\underline{V} \wedge \underline{\hat{e}}) = \underline{V}\,(\underline{\hat{e}} \bullet \underline{\hat{e}}) - \underline{\hat{e}}\,(\underline{\hat{e}} \bullet \underline{V})$$

$$\therefore\ \underline{V} = \underline{U} + \underline{W} = U\,\underline{\hat{e}} + W\,\underline{\ddot{e}} \qquad \text{where: } U = \underline{\hat{e}} \bullet \underline{V} \text{ and } \underline{W} = \underline{\hat{e}} \wedge (\underline{V} \wedge \underline{\hat{e}})$$

When a source electron at $\underline{x}'_n$ at time t'_n chooses to interact with another (target) electron at $\underline{x}_n$ at time t_n then the light-vector $\underline{c}_n$ is defined as: $\underline{c}_n = c\,\underline{\mathring{A}}_n$ where: $\underline{\mathring{A}}_n = (\underline{x}_n - \underline{x}'_n) / |\underline{x}_n - \underline{x}'_n|$; in other words, the source-to-target direction always defines the directionality of the light-vector whether the interaction is retarded ($t_n > t'_n$) or advanced ($t_n < t'_n$). In order to make the small twisting effect of the far interaction consistent with the **Digital Electron Model** [163] the electron torque will now be assigned the same <u>chirality</u>. So, if a negative electron, moving with velocity $\underline{u}'_{n-1}$, sends an impulse $\Delta\underline{\mathbf{I}}_{n+1}$ <u>to</u> another electron (of either charge) it will undergo a reaction impulse $\Delta\underline{\mathbf{I}}'_{n+1}$. When this interaction is 'retarded' then the reaction is in the direction defined by: $-\,\underline{\ddot{e}}_n$ (or $+\,\underline{\ddot{e}}_n$ if 'advanced') where the unit velocity vector is defined by: $\underline{\hat{u}}'_n \equiv \underline{u}'_n / u'_n$. These directions are reversed when the emitting particle is a positively charged electron. Since linear momentum is always conserved across each and every interaction the receiving electron will always receive an impulse in the opposite direction; that is to say: $\Delta\underline{\mathbf{I}}_{n+1} = -\,\Delta\underline{\mathbf{I}}'_{n+1}$. Thus, a target electron (of charge Q), when it interacts at $[\underline{x}_n\,;\,t_n]$ with a source electron of charge Q′ at $[\underline{x}'_n\,;\,t'_n]$ that was moving with velocity $\underline{u}'_{n-1}$ just before the interaction (time always increments positively in this theory) receives a remote impulse $\Delta\underline{\mathbf{I}}^{\sigma}_{n+1}$ (where σ is the **temporality** factor: $\sigma = -1$ if retarded or $\sigma = +1$ if advanced).

$$\text{Far Impulse: } \Delta\underline{\mathbf{I}}^{\sigma}_{n+1} \equiv \sigma\, Q'\, m\, b\, \underline{\ddot{e}}_n$$

It is plausible that the transverse impulse is completely defined by the prior velocities of the two electrons; i.e. $\underline{u}_{n-1}$ and $\underline{u}'_{n-1}$. Since the total momentum is conserved (i.e. $\underline{u}_n + \underline{u}'_n = \underline{U}_0$) it is likely that it depends on the difference ($\underline{u}_{n-1} - \underline{u}'_{n-1}$). The charge of the electrons is insignificant during this part of the far interaction although there is always a tiny longitudinal part that can be either repulsive or attractive that **distinguishes** far interactions between similar or oppositely charged electrons.

Parallel Interactions minimize Total Time

When an isolated electron is moving between infrequent interactions it is 'generating' kinetic action $\Delta\mathcal{A}^K{}_n$ at the rate of $h/2$ action units over time periods Δt_n while moving with longitudinal speed u_n (or kinetic energy $\mathcal{K}_n = \frac{1}{2}\, m\, u_n^2$). [164] The next interaction **may** only occur for this electron (after its last interaction at time t_n) after a time interval T_n, where:

$$\mathrm{T}_n = \eta_n\, \Delta t_n = \eta_n\, h / 4\mathcal{K}_n \qquad \text{where} \quad \eta_n = 1, 2, \ldots$$

If, after one of these valid intervals T_n, this (target) electron interacts with another electron that is 'far' away, this interaction will be equivalent to the impact of a transverse impulse $\Delta\mathbf{I}_T$ on both electrons. This will produce the least change in the rate of generating kinetic action, in the smallest interval T_n on the target electron, if this impulse is absorbed in the direction of motion $\underline{\hat{u}}_n$ as the least variation in time needs the greatest change in the kinetic energy; so (assuming $u_n >> \delta u_n = b$):

$$\delta\,[\,\mathcal{A}^K{}_n\,] = \delta\,[2\,\mathcal{K}_n\,\Delta t_n] = m\,\Delta t_n\,\delta\,[\underline{u}_n \bullet \underline{u}_n] = \Delta t_n \left\{\underline{u}_n\right\} \bullet m\,\delta\underline{u}_n = \tfrac{1}{2}\,\Delta t_n\,[\underline{u}_n + (\underline{u}_n + \delta\underline{u}_n)] \bullet \Delta\underline{\mathbf{I}}_T \approx \Delta t_n\, u_n\,(\underline{\hat{u}}_n \bullet \Delta\underline{\mathbf{I}}_T)$$

This occurs when $\underline{\ddot{e}}_n = \underline{\hat{u}}_n$ but as the far interaction preserves total momentum, this also occurs when $\underline{\hat{u}}'_n$ is anti-parallel to $\underline{\ddot{e}}_n$; i.e. when source and target impulses are orthogonal to their line-of-centers. So, if the receiving impulse $\Delta\underline{\mathbf{I}}_T$ on the target electron increases its kinetic energy then the reaction impulse $\Delta\underline{\mathbf{I}}'_T$ on the source electron must decrease its kinetic energy. This means that both electrons must be <u>moving in the same direction</u> at the times when they interact (this is <u>opposite</u> to the intuition that they are moving in opposite directions in a collision – instantaneous forces). This also implies that parallel momentum changes can be propagated across multiple electron pairs over a series of several interactions; this is another proven property of 'light'. Since these two electrons are very far apart when they interact and must be on their respective light-cones (see §6.1.2) then they will effectively stay on their light-cones (at least to second order in u_n^2/c^2) for the next few mutual interactions provided the interaction intervals T_n are not too large. Thus, this 'far' impulse exchange mechanism provides a <u>realistic microscopic model</u> of the transverse force-density (field) oscillations predicted by Maxwell's Equations and the CEM model of light propagating through a medium. This latter model was based on the idea that the vector potential density remained parallel to variations in the average source current density.

6.2.5 THE 2D TWO-ELECTRON SYSTEM

Interaction Labeling

This section investigates an imaginary system consisting of only two negatively charged electrons; in reality, no electron can be isolated from the rest of the universe and the remote EM interaction has infinite range, so that everything ultimately then interacts with everything else (eventually). The pedagogical model investigated here will be used to gain insights about the remote interaction that acts overwhelmingly in a transverse mode (relative to the spatial locations), in contrast to the (earlier) longitudinal interaction that dominates when the spatial separations are small. In attempting to develop the 2D trajectories for two-electron scattering it should prove useful to retain as much of the long-range 1D longitudinal solution as possible [160]; the two electrons will be considered to be first approaching each other from opposite directions, each at light-speed c.

Imagine a right-handed Cartesian reference frame [$\underline{\hat{e}}_1$, $\underline{\hat{e}}_2$, $\underline{\hat{e}}_3$] with the x-z axes in the plane of the page with the z-axis (oriented across the page from left to right) and x-axis (oriented vertically on the page) so the y-axis emerges out of the page. By convention, electron #1 will be restricted to the positive z-axis and electron #2 will be limited to the negative z-axis. Again, electron #2 initially moves in the positive z-direction (the 'inward' phase) before it reverses its motion and then moves (in the later or 'outward' phase) in the negative z-direction; electron #2's motion in the z-direction is the complement of electron #1's motion. The interaction region is defined by the volume $z = \pm Z_0$ and $x = \pm X_0$ while the interaction extends over the temporal duration $t = \pm T_0$. The target electron's closest approach to the origin occurs at $z = z_0$ and $x = x_0$.

In this analysis the '***Asymmetric Temporal***' labeling scheme will be used, based on the time evolution of the interaction events experienced by the 'target' electron (#1); this emphasizes this electron's *outbound* event set [t_j] where $1 \le j \le N$. A complementary set of events [t'_j] is experienced by the 'source' electron #2. The j^{th} interaction is experienced by both electron #1 at [t_j ; $\underline{x}_j$] and by electron #2 at [t'_j ; $\underline{x}'_j$]. Conservation of momentum implies that as electron #1 is accelerating away from the origin (in the positive z-direction) then electron #2 must be decelerating as it moves too on its inward phase (also in the positive z-direction) while losing momentum in the z-direction to electron #1. The space and time notation is extended to the target electron's inward phase by adopting the convention here that: $z_{-j} = \underline{z}_j$ and $x_{-j} = -\underline{x}_j$ for $1 \le j \le N$. The source electron's co-ordinates are labeled accordingly so that:

$$[\ \underline{x}'_j = -\underline{x}_{N-j+1} \ \ \& \ \ t'_j = -t_{N-j+1}\ ] \quad \text{and} \quad [\ \underline{x}'_{-j} = -\underline{x}_{j-N-1} \ \ \& \ \ t'_{-j} = -t_{j-N-1}\ ] \quad \text{for } 1 \le j \le N$$

The Asymmetric labels [j] are related to the (monotonic) **Event** labels [n] by the formula: $j = n + 1 - N$

Thus, each intra-electron separation vector $\underline{S}_n$ defines each 'light-vector' $\underline{c}_n$ and are defined by:

$$\underline{S}_n \equiv \underline{x}_n - \underline{x}'_n = \underline{c}_n (t_n - t'_n) \equiv \underline{c}_n T_n \quad \text{where} \quad -N \le n \le -1 \ \ \& \ \ 1 \le n \le N$$

Parallel Interactions

The most significant feature of this solution is that all the interactions between each electron, in either their inward or outward phase, are ***nearly in parallel*** and make the same angle ϕ in space (called here the Interaction Angle); this is equivalent to the QED statement that "all real photons travel in parallel". However, it is possible to construct trajectories that cross the z-axis more than once so there are actually two sets of parallel interactions, one set making a positive angle and one set making a negative angle. The positive angle set occurs when the target electron is above the z-axis (positive x) while the negative angle set occurs when the target electron is below the z-axis (negative x). These may be consolidated into a single formulation by introducing the *Phase Parameter* σ_n defined as:

$$\textit{Phase Parameter}: \ \sigma_n = +1\ [\ x_n \ge 0\ ] \text{ and } \sigma_n = -1\ [\ x_n < 0\ ]$$

Thus, the parallel requirement implies that each $\underline{c}_n$ must belong to one of these two sets: $\underline{c}_n \equiv \sigma_n \underline{c} \equiv c\, \underline{\hat{a}}_n$

Since $\underline{\hat{a}}_n \bullet \underline{\hat{a}}_n = 1$ and $(\sigma_n)^2 = 1$ then $\underline{c}_n \bullet \underline{c}_n = c^2$ as required.

$$\therefore\ \underline{S}_n = S_n \underline{\hat{a}}_n = \underline{c}_n T_j \quad \therefore\ S_n = c\, T_n \quad \& \quad \underline{\hat{e}}_3 \bullet \underline{\hat{a}}_n = \cos\phi \quad \& \quad \underline{\hat{e}}_1 \bullet \underline{\hat{a}}_n = \sigma_n \sin\phi \quad \therefore\ \underline{\hat{a}}_n = \cos\phi\, \underline{\hat{e}}_3 + \sigma_n \sin\phi\, \underline{\hat{e}}_1$$

It is important to notice that each pair of impulses are equal in magnitude, $\Delta \mathbf{I}_0 = mb$ but opposite in direction: $\Delta \underline{\mathbf{I}}'_n = -\Delta \underline{\mathbf{I}}_n$. Thus, every impulse experienced by the target electron has the form: $\Delta \underline{\mathbf{I}}_n = \Delta \mathbf{I}_0\, \underline{\tilde{a}}_n$ and so: $\underline{\hat{a}}_n \bullet \underline{\tilde{a}}_n = 0$ since the remote EM impulses are effectively transverse (i.e. orthogonal) to the separation vectors.

$$\therefore\ \underline{\tilde{a}}_n = \sin\phi\, \underline{\hat{e}}_3 - \sigma_n \cos\phi\, \underline{\hat{e}}_1$$

The choice of sign here is based on the requirement that during the inbound phase the target electron must be decelerated as fast as possible so that it can rebound at its closest point (when its velocity in the z-direction is zero) and return outwards. So, in every event, the z-direction of the impulses experienced by electron #1 are all in the positive z-direction while those for electron #2 are all in the negative z-direction. It will be seen that the direction of the impulses in the x-direction, at each event are vital to finding the minimum action solution. This depends critically on the direction of the source electron's velocity prior to each interaction event it participates in according to be in full compliance with the vector definition of the remote EM interaction defined earlier in §6.2.2. The Interaction-Angle ϕ is actually defined by the ratio of the initial and intermediate spatial separations at the target electron's final location.

$$\underline{S}_N = S_N \, \underline{\hat{a}}_N = S_N (\cos\phi \, \underline{\hat{e}}_3 + \sin\phi \, \underline{\hat{e}}_1) = (z_N - \underline{z}'_N)\, \underline{\hat{e}}_3 + (x_N - x'_N)\, \underline{\hat{e}}_1 = (z_N + z_0)\, \underline{\hat{e}}_3 + (x_N + x_0)\, \underline{\hat{e}}_1$$

$$\therefore \ \tan\phi = (X_0 + x_0) / (Z_0 + z_0) \quad \therefore \ \tan\phi = X_0 / Z_0 \quad \text{using here the 'optical' approximation:} \quad X_0 >> x_0 \ \ \& \ \ Z_0 >> z_0$$

Oscillating Trajectories

The most general trajectory involves each electron crossing the z-axis $(1 + \Xi)$ times where $\Xi = 0, 1, 2, \ldots$. We will use the convention that the target electron always crosses the z-axis in the positive-x direction (with speed W_0) when it is closest to the origin then the target electron must begin its journey at $x_N = -X_0$ when $\Xi = 0, 2, 4, \ldots$ and $x_N = X_0$ when $\Xi = 1, 3$, etc. Maximum symmetry occurs if each electron crosses the z-axis involving 2Γ interactions, the first half of these accelerate the electron's transverse speed from zero to W_Γ while the second half of these interactions decelerate its speed back to zero. As the interaction angle ϕ is constant in magnitude it will be seen (next) that the electrons will move between $x = -X_0$ and X_0. This generates a cyclic or 'wave-like' motion along the x-axis such that the interaction events in each cycle can be labeled by a cyclic x-index γ that takes on the consecutive values: $\gamma = 0, 1, 2, \ldots, (2\Gamma - 1)$; this is shown schematically next (Γ=3).

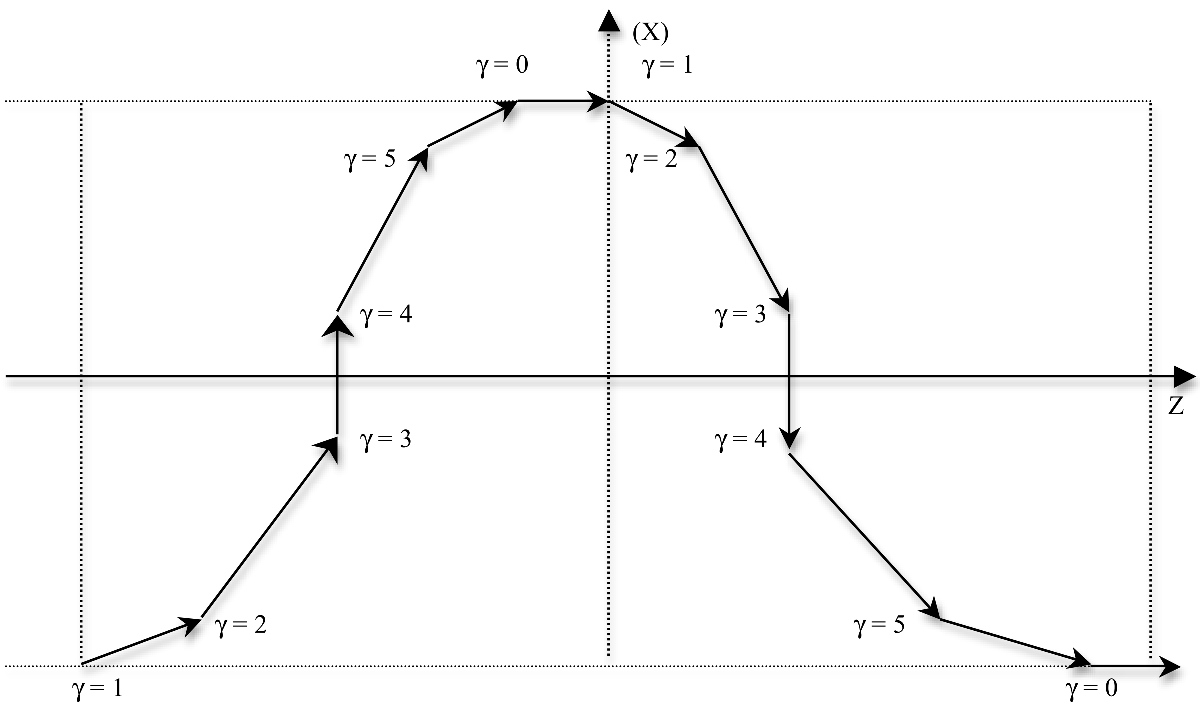


Fig. 4 Remote 2D Transverse Motion Schematic (Γ = 3)

Since both the inbound and outbound phases each require N impulses, all in the same direction along the z-axis, to change each electron's speed from zero to light-speed then the oscillating trajectory scheme requires the following constraint:

$$N = (1 + 2\Xi) * \Gamma \qquad \text{While} \quad \min[\Gamma] = 2 \ \text{with} \ \max[\Xi] = N/4 \ \& \ \max[\Gamma] = N \ \text{with} \ \min[\Xi] = 0$$

Each 'half-wave' set of indexes [γ] are related to the global index set [j] by the equation: $\gamma = j + \Gamma - \Gamma \, \mathrm{Int}[(j+\Gamma)/\Gamma]$

Almost Parallel Interactions

Each of the interactions, in the Oscillating Model, actually occurs at the varying angle ϕ_n, where n is the interaction index. This is defined by the angle between $\underline{x}_n$ and $\underline{x}'_n$ and the z-axis; all these angles are very close to the main interaction angle ϕ.

$$\therefore\ \tan\phi_n = x_n / L_n \ \ \& \ \ \tan\phi'_n = x'_n / L'_n \ \ \therefore\ 2\,z_n = z_n - z'_n = L_n + L'_n = (x_n + x'_n) / \tan\phi_n = 2\,x_n / \tan\phi_n \approx 2Z_0$$

$$\therefore\ \tan\phi_n = x_n / z_n \quad \text{But } 0 \le x_n \le R_0 \quad \& \ \ \tan\phi = x_n / z_n \approx x_n / Z_0 \ \ \therefore\ \tan\phi_n \approx (Z_0 / z_n)\tan\phi \approx \tan\phi$$

The maximum value of z_n is Z_0 so that every interaction angle is constrained to lie within the interaction cone (angle ϕ). Since Z_0 is very large ('far' approximation) then successive interactions (i.e. a "photon") appears to 'go in a straight line'. As in the longitudinal model, the accelerating impulses on the target electron (#1) in its outgoing phase, originate at the source electron (#2) during its inward phase (as both must be moving in the same direction). This means that the first interaction (n = 1) occurs when electron #1 has reached its closest approach to the origin, just beyond the z-axis ($\gamma = \Gamma$) while electron #2 has reached its first possible interaction location at its furthest point from the z-axis ($\gamma = 0$). Here, the index γ refers to the 'half-wave' offsets in each 'block' of transverse motions in the ζ set of partial motions; that is to say, using a new 'index' $j = \gamma + 2\Gamma\,\zeta$ where: $[\,\zeta = 0, 1, 2, \ldots, \Xi]$.

In this diagram, the axes are chosen so that the initial separation vector $\underline{S}_1$ (or light-vector $\underline{c}_1$) goes through the origin O. In the outward-bound phase (**Asymmetric** labeling) the target electron (#1) has a small initial velocity $\underline{u}_0$ (it has just 'turned around') at $t = t_1$ in the upper right-hand quadrant at $[x_1 = r_0,\ z_1 = z_0]$ while the source electron (#2) is moving with velocity $\underline{U}_0$ (at speed *c*) at the time $t = t'_N = -\,t_N$ in the lower left-hand quadrant at $[x'_1 = -\,R_0,\ z'_1 = -\,Z_0]$. As in the 1D model, the initial 'far' distances are vastly greater than the initial 'near' distances i.e. $Z_0 >> z_0$ and $R_0 >> r_0$; it will also be assumed here that $Z_0 >> R_0$.

$$\tan\phi_1 = R_0 / (Z_0 + z_0) \approx R_0 / Z_0 = \tan\phi << 1 \qquad \therefore\ \phi_1 \approx \phi$$

FIRST (RETURN-PHASE) INTERACTION

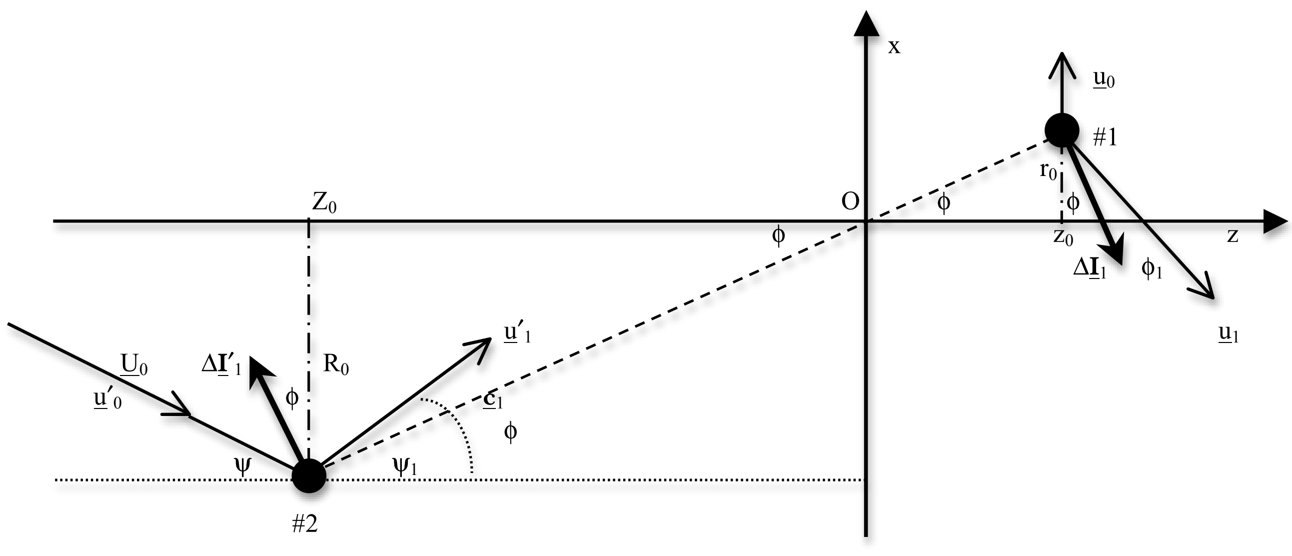


Fig. 5 First (Return) Interaction in the X-Z Plane

In this model, the initial speeds and velocities of the two electrons are critical to the subsequent dynamics. The key decision is to have the target electron not moving in the z-direction just prior to its first return interaction. It achieved this condition by completing the first half of its journey – slowing down from light-speed when it first reached $z = Z_0$; the story resumes as the source electron first reaches $z = -Z_0$ (remember, in this model of EM there are always TWO times involved).

All velocities can be resolved into two components: $\underline{u}_j \equiv \underline{V}_j + \underline{W}_j = V_j\,\hat{\underline{e}}_3 + W_j\,\hat{\underline{e}}_1$ At the turnaround: $\underline{V}_0 = 0$

The transverse velocities increase from zero at the extrema ($x = \pm R_0$) to the maximum value $\underline{W}_0$ as they cross the z-axis.

Newton's Impulse Law

Now the maximum value of each impulse is mb which is a factor N_0 smaller than mc (§6.2.2) so the maximum radial impulse at any interaction cannot exceed mb this means that the maximum speed in the transverse direction cannot exceed b. So, it will be useful to define two baseline speeds:

$$b_z \equiv b \sin\phi \quad \& \quad b_R \equiv b \cos\phi \quad \therefore\ b_R / b_z = 1/\tan\phi = Z_0 / R_0 >> 1 \quad \therefore\ \phi << 1$$

$$\Delta\underline{\mathbf{I}}^L{}_j = m\, b \sin\phi_j\, \underline{\hat{e}}_3 \quad \& \quad \Delta\underline{\mathbf{I}}^R{}_j = \pm\, m\, b \cos\phi_j\, \underline{\hat{e}}_1 \quad \& \quad \Delta\underline{\mathbf{I}}'_j = -\Delta\underline{\mathbf{I}}_j \quad \& \quad \tan\phi_j = \Delta\mathbf{I}^L{}_j / \Delta\mathbf{I}^R{}_j$$

$$\therefore\ \Delta\underline{\mathbf{I}}_1 = \Delta\mathbf{I}_0 (\sin\phi_1\, \underline{\hat{e}}_3 - \cos\phi_1\, \underline{\hat{e}}_1) = m\, b\, (\sin\phi\, \underline{\hat{e}}_3 - \cos\phi\, \underline{\hat{e}}_1) = m\, (b_z\, \underline{\hat{e}}_3 - b_R\, \underline{\hat{e}}_1) = -\Delta\underline{\mathbf{I}}'_1$$

All source velocities can be resolved into two components (this is only a 2D model): $\underline{u}'_j = \underline{V}'_j + \underline{W}'_j = V'_j\, \underline{\hat{e}}_3 + W'_j\, \underline{\hat{e}}_1$

Newton's Second Law of Motion is extended here to asynchronous interactions: $\Delta\underline{\mathbf{I}}_j = m\, \Diamond\underline{V}_{j-1} = m\, b\, \underline{\tilde{a}}_j = -m\, \Diamond\underline{V}'_{j-1}$

Here, $\Diamond$ is the **point-difference** operator that only applies **at** the point of interaction; it was introduced in the fourth paper in the analysis of enhanced finite difference operators [157] so that the total discrete change: $\Delta = \underline{\Delta} + \Diamond$, where $\underline{\Delta}$ is the **extended-difference** operator that applies between interactions. (NB First Return Interaction: j = 1).

At the **target** electron, the impulse $\Delta\underline{\mathbf{I}}_1$ changes its initial velocity from $\underline{u}_0$ to $\underline{u}_1$, where: $\underline{u}_0 = \underline{W}_0 = -\underline{W}'_0 \approx \Gamma\, b_R\, \underline{\hat{e}}_1$

Newton's Impulse Law: $\Delta\underline{\mathbf{I}}_1 = \Diamond\underline{p}_0 = m\, \Diamond\underline{u}_0 = m\, (\underline{u}_1 - \underline{u}_0) = m\, [(\underline{V}_1 + \underline{W}_1) - (\underline{V}_0 + \underline{W}_0)] = m\, [(\underline{V}_1 - \underline{V}_0) + (\underline{W}_1 - \underline{W}_0)]$

$$\therefore\ b\, (\sin\phi\, \underline{\hat{e}}_3 - \cos\phi\, \underline{\hat{e}}_1) = b_z\, \underline{\hat{e}}_3 - b_R\, \underline{\hat{e}}_1 = \underline{V}_1 + (\underline{W}_1 - \underline{W}_0) = V_1\, \underline{\hat{e}}_3 + (W_1 - b_R\, \underline{\hat{e}}_1) \quad \therefore\ V_1 = b_z \quad \& \quad W_1 = (\Gamma - 1)\, b_R$$

$$\therefore\ \underline{u}_1 = b_z\, \underline{\hat{e}}_3 + (\Gamma - 1)\, b_R\, \underline{\hat{e}}_1 \quad \therefore\ \underline{u}_1 \approx (\Gamma - 1)\, b_R\, \underline{\hat{e}}_1 \quad \therefore\ \tan\phi_1 = V_1 / W_1 = b_z / (\Gamma - 1)\, b_R = 1/(\Gamma - 1) \tan\phi$$

$$\therefore\ \tan^2\phi \approx \phi^2 \approx 1/(\Gamma - 1) << 1 \quad \therefore\ \Gamma >> 1$$

At the **source** electron, the impulse $\Delta\underline{\mathbf{I}}'_1$ changes its initial velocity from $\underline{u}'_0$ to $\underline{u}'_1$, where $\underline{u}'_0 = c\, \underline{\hat{e}}_3$ i.e. $V'_0 = c$ & $\underline{W}'_0 = 0$

$$\therefore\ \Delta\underline{\mathbf{I}}'_1 = \Diamond\underline{p}'_1 = m\, \Diamond\underline{u}'_0 = m\, (\underline{u}'_1 - \underline{u}'_0) = m\, [(\underline{V}'_1 + \underline{W}'_1) - (\underline{V}'_0 + \underline{W}'_0)] = m\, [(\underline{V}'_1 - \underline{V}'_0) + (\underline{W}'_1 - \underline{W}'_0)]$$

$$\therefore\ -b\, (\sin\phi\, \underline{\hat{e}}_3 - \cos\phi\, \underline{\hat{e}}_1) = -(b_z\, \underline{\hat{e}}_3 - b_R\, \underline{\hat{e}}_1) = (V'_1 - V'_0)\, \underline{\hat{e}}_3 + W'_1\, \underline{\hat{e}}_1 \qquad \therefore\ V'_1 = c - b_z \approx c \quad \& \quad W'_1 = b_R$$

The target electron moves a distance Δx_1 as a result of this first (return) interaction, where: $\Delta x_1 = W_1\, \Delta t_1$. Here, Δt_1 is the time difference between the first impulse and second impulse received at the target electron. Similarly, the source electron moves a distance $\Delta x'_1$ as a result of this first (return) interaction, where: $\Delta x'_1 = W'_1\, \Delta t'_1$. Here, $\Delta t'_1$ is the time difference between the first impulse and second impulse experienced at the source electron. The motion of these two electrons will be cyclic if they both cross the distance R_0 in the same time, $\mathcal{T}'_0$ (referred to here as the micro-cycle period). The maximum symmetry is then achieved if $\mathcal{T}'_0$ is independent of Γ. This implies that: $\Delta x_1 = \Delta x'_{\Gamma+1}$ or $W_\gamma\, \Delta t_\gamma = W'_{\Gamma+\gamma'}\, \Delta t'_{\Gamma+\gamma'}$.

Space-Time Integrity

The **GIC** condition (§6.2.4) may be projected longitudinally (z-direction) and horizontally (x-direction), while noting that:

$$\underline{\hat{e}}_3 \bullet (\underline{c}_{n+1} - \underline{c}_n) = c\, (\cos\phi_{n+1} - \cos\phi_n) \approx -c/2\, (\phi^2{}_{n+1} - \phi^2{}_n) \approx 0 \ \text{ (to Order } \phi_n \text{)} \quad \text{i.e. almost parallel.}$$

$$\therefore\ \underline{\hat{e}}_3 \bullet [\, (\underline{c}_{n+1} - \underline{u}_n)\, \Delta t_n = (\underline{c}_{n+1} - \underline{u}'_n)\, \Delta t'_n \,] \quad \therefore\ V_n\, \Delta t_n - V'_n\, \Delta t'_n = (\underline{\hat{e}}_3 \bullet \underline{c}_{n+1})\, (\Delta t_n - \Delta t'_n) \approx c \cos\phi\, (\Delta t_n - \Delta t'_n)$$

This resembles the GIC for the 1D longitudinal model with the solutions: $\Delta t_n = n\, \Delta T_0$ & $V_n = n\, B$ (**Event** labels).

$$\therefore\; c \cos\phi\, \Delta T_0\, (n - n') = B\, \Delta T_0\, (n^2 - n'^2) = B\, \Delta T_0\, (n - n')\,(n + n') \qquad \therefore\; B = b \cos\phi \quad \& \quad n + n' = N_0$$

$$\therefore\; \Delta t_n = n\, \Delta T_0 \;\; \& \;\; V_n = n\, b \cos\phi \quad \& \quad \Delta t'_n = (N_0 - n)\, \Delta T_0 \;\; \& \;\; V'_n = (N_0 - n)\; b \cos\phi$$

This is very similar to the one-dimensional solution but modified by the cosine of the original interaction angle ϕ.

The next diagram illustrates the impulses and light-vectors of two consecutive interactions in the longitudinal (r-z) plane. Each light-vector $\underline{c}_n$ is defined as originating in space and time at the source electron (#2) and terminating at the target electron (#1) for the interaction labeled n. It is important to note that this is a geometric construction across 3D space and does **not** imply that there is a real physical entity (called a 'photon') that physically moves across this spatial difference.

In this diagram the $(n+1)^{th}$ impulse at the source $\Delta\underline{\mathbf{I}}'_{n+1}$ is shown to be resolved radially $\Delta\underline{\mathbf{I}}^{R\prime}_{n+1}$ and longitudinally $\Delta\underline{\mathbf{I}}^{L\prime}_{n+1}$. Note that the two impulses are orthogonal to their light-vector and so are offset at the same angle ϕ_n to their radial vector $\underline{\hat{a}}_n$ and note also that (by convention) the target electron in this outward phase lies in the positive (r-z) quadrant ($0 < \phi_n < \pi/2$).

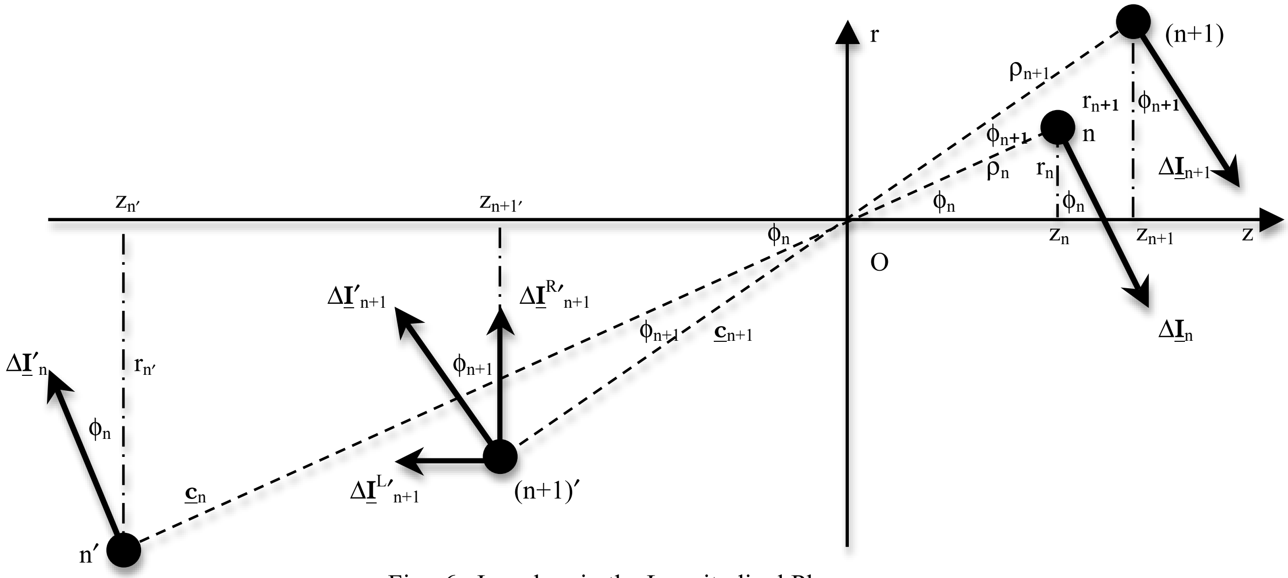


Fig. 6 Impulses in the Longitudinal Plane

Extending this to the horizontal direction: $\underline{\hat{e}}_1 \bullet \underline{c}_n = c \sin\phi_n$ & $t_n - t'_n = (n - n')\, \Delta T_0 = [(n+k) - (n'+k)]\, \Delta T_0 = t_{n+k} - t'_{n+k}$

$$\therefore\; \underline{\hat{e}}_1 \bullet [\, (2\, \underline{c}_{n+1} - \underline{c}_n)\, (t_n - t'_n) = (\underline{u}_n\, \Delta t_n - \underline{u}'_n\, \Delta t'_n)] = W_n\, \Delta t_n - W'_n\, \Delta t'_n = c\, (2\sin\phi_{n+1} - \sin\phi_n)\, (t_n - t'_n)$$

$$\therefore\; (n\, W_n - n'\, W'_n) \approx c\, (2\sin\phi - \sin\phi)\, (n - n') = c \sin\phi\, (n - n') = N_0\, b \sin\phi\, (n - n') = (n + n')\, b \sin\phi\, (n - n')$$

$$\therefore\; (n\, W_n - n'\, W'_n) \approx b \sin\phi\, [n\, n - n'\, n'] \qquad \therefore\; W_n = n\, b \sin\phi \quad \& \quad W'_n = n'\, b \sin\phi = (c - n\, b)\, \sin\phi$$

$$\therefore\; u_n^2 = V_n^2 + W_n^2 = (n\, b)^2\, [\cos^2\phi + \sin^2\phi] \quad \therefore\; u_n = n\, b \quad \& \quad u'_n = (c - n\, b) \quad [\text{for } 0 \le n \le N_0]$$

Thus, the longitudinal speed V_j always increases monotonically as j increases from 1 to N_0. $\therefore\; V_j = V_0 + j\, b \cos\phi$

The final boundary condition is that the target electron moves in the positive z-direction: $\underline{V}_N = c\, \underline{\hat{e}}_3 \;\; \therefore\; V_0 = 0$

The oscillatory motion means that the transverse motion is '**harmonic**' with the electron's transverse speed W_γ varying from zero at its extrema ($\gamma = 0$) to its maximum value W_Γ as it crosses the z-axis at $\gamma = \Gamma$, therefore the change in transverse speed ΔW_γ varies in an oscillating '**square wave**' manner – the integer-equivalent of a continuous sine wave.
This is described algebraically by the **square-wave function Ψ**, defined through the universal sign function sgn[x]:

$$\Psi[n\, ;\, \Gamma] = \mathrm{sgn}[\, \sin[(n + \tfrac{1}{2})\, \pi/\Gamma]\,] \quad \text{where} \quad \mathrm{sgn}[n] = +1 \;\text{ if } n \ge 0 \;\text{ and }\; -1 \;\text{ if } n < 0 \quad [\text{all integer n and } \Gamma].$$

For example, if $\Gamma = 3$ then: $\Psi[n\,;\,3] = +1$ if $n = 0, 1, 2; 6, 7, 8; 12, \ldots$ & -1 if $n = 3, 4, 5; 9, 10, 11; 15, \ldots$

$$\therefore \; W_{\gamma+1} = W_\gamma + \Delta W_\gamma \quad \text{with } W_0 = 0 \;\&\; \Delta W_\gamma = \Psi[\gamma\,;\,\Gamma]\, b \sin\phi \quad \text{for } [0 \le \gamma \le 2\Gamma - 1]$$

$$\therefore \; W_\gamma = \gamma\, b \cos\phi = W_j = j\, b \sin\phi \quad \therefore \; \tan\phi = \gamma / j \le 1 \quad \therefore \; \gamma \text{ is cyclic over a period } 2\Gamma \quad \therefore \; (1 + 2\Xi)\Gamma = N_0$$

$$\therefore \; V_j = j\, b \cos\phi \quad \& \quad W_\gamma = \gamma\, b \cos\phi \; [0 \le \gamma \le \Gamma] \;\&\; W_\gamma = (2\Gamma - \gamma)\, b \cos\phi \; [\Gamma + 1 \le \gamma \le 2\Gamma - 1]$$

Quantizing Kinetic Action

Central to the present theory is the idea that action is always quantized. Since the dynamic action is already quantized this leaves the quantization of the kinetic action of each electron (see section 6.2.2); thus for electron #1 at the n^{th} interaction:

$$\Delta\mathcal{K}_{n-1}\, \Delta t_n = \pm h / 4 \qquad \text{where: } \Delta t_n = t_{n+1} - t_n \;\&\; \Delta\mathcal{K}_{n-1} = \mathcal{K}_n - \mathcal{K}_{n-1}$$

$$\therefore \; \mathcal{K}_n = \tfrac{1}{2} m\, (u_n)^2 = \tfrac{1}{2} m\, [(V_n)^2 + (W_n)^2] \quad \therefore \; \Delta\mathcal{K}_{n-1} = \tfrac{1}{2} m [\, (V_n + V_{n-1})\, \Delta V_{n-1} + (W_n + W_{n-1})\, \Delta W_{n-1} \,]$$

$$\therefore \; \Delta\mathcal{K}_{n-1} = m\, b^2\, [(\, n - \tfrac{1}{2}) \cos^2\phi + (\, n - \tfrac{1}{2}) \sin^2\phi)] = (\, n - \tfrac{1}{2})\, m\, b^2 \quad \therefore \; \Delta t_n = h / 4\, (\, n - \tfrac{1}{2})\, m\, b^2 = N_0^2\, \lambda_C / 4(n - \tfrac{1}{2})\, c$$

$$\text{For } n=1 \quad \Delta\mathcal{K}_0 = \tfrac{1}{2} m\, b^2 = m\, c^2 / 2\, N_0^2 \quad \therefore \; \Delta t_1 \approx \mathcal{T}_C\, N_0^2 / 2 \approx 1 * 10^{-3} \text{ secs.}$$

Where: $\mathcal{T}_C$ is the **Compton Period**: $\mathcal{T}_C = \lambda_C / c \equiv h / m\, c^2 \approx 3 * 10^{-21}$ secs.

But , from above, $\Delta t_n = n\, \Delta T_0 \;\; \therefore \Delta T_0 = \Delta t_1 = h / 2\, m\, b^2 = N_0^2\, (\pi/\alpha)\, \tau$ where τ is the 'nuclear' chronon, $\tau = e^2 / m\, c^3$

The Monotonic (Parabolic) Solution ($\Xi = 0$)

The monotonic solution is the simplest trajectory as each electron only crosses the z-axis once when it is closest to the origin this means that the crossover number Ξ is zero so that the cyclic number $\Gamma = N$. This extremum solution is also monotonic for the x-component of velocity when W_j has the same sign for all j; this occurs when: $\tan\phi = 1$ ($\phi = \pi/4$) $X_0 = Z_0$
This resembles a parabolic trajectory for each of the electrons as they swing in from their initial 'extremal' points, as they exchange longitudinal momentum for horizontal momentum. In fact, this is the **only** harmonic solution that is consistent with the solutions found above. That is, when $\Gamma = N_0$ and $W_\gamma = \gamma\, b \cos\phi = W_n$ only when $\gamma = n$.

$$\therefore \; W_{j+1} = W_j + \Delta W_j \quad \text{with } W_N = 0 \;\&\; \Delta W_j = -\, b \cos\phi \quad [\text{for } 1 \le j \le N]$$

$$\therefore \; V_n = V_{n-1} + \Delta V_{n-1} = n\, b \sin\phi \quad \& \quad W_n = W_{n-1} + \Delta W_{n-1} = W_0 - n\, b \cos\phi \quad [1 \le n \le N]$$

Applying the boundary conditions: $c = N\, b \sin\phi \;\&\; 0 = W_0 - N\, b \cos\phi \;\; \therefore \; W_0 = N\, b \cos\phi = c / \tan\phi \ge c$

$$\therefore \; \phi = \pi/4 \;\; \therefore \; X_0 = Z_0 \;\; \therefore \; c = N\, b / \sqrt{2} = N_0\, b \;\; \therefore \; \mathbf{N} = N_0 \sqrt{2} \quad \therefore \; V_j = j\, c / N \;\&\; W_j = (N - j)\, c / N$$

$$\therefore \; V_j = j\, b \sin\phi = j\, c / N \;\&\; W_j = (N - j)\, b \cos\phi = (N - j)\, b\, c \sqrt{(1 - (N_0 / N)^2)} \quad \& \;\; \Delta V_j = b$$

$$\therefore \; u_j = [j\, \underline{\hat{e}}_3 + (N - j)\, \underline{\hat{e}}_1]\, c / N \quad \therefore \; (u_j)^2 = [j^2 + (N - j)^2]\, (c / N)^2 \equiv G_j\, (c / N)^2$$

The kinetic function, $G_j = [j^2 + (N - j)^2]$ is a slowly varying function of j with a minimum of $N^2/2$ around $j = N/2$ (M) and maxima of N^2 around $j = N$ and $j = 0$; so that G_j is decreasing between j = 0 and N/2 and increasing from N/2 to N.

$$\therefore \; \mathcal{K}_j = \tfrac{1}{2} m\, c^2\, G_j / N^2 \quad \therefore \; \mathcal{K}_j \text{ decreases from } \tfrac{1}{2} m\, c^2 \text{ to } \tfrac{1}{4} m\, c^2 \text{ and increases back to } \tfrac{1}{2} m\, c^2 \text{ as j goes from 0 to N.}$$

$$\therefore \; \Delta t_n = \mathcal{T}_C\, N^2 / 4\, |N + 1 - 2n| \quad \therefore \; \Delta t_M = (N/4)\, \mathcal{T}_C = (3\pi / \alpha^4\, 4\sqrt{2})\, \mathcal{T}_C \approx 0.58 * 10^9\, \mathcal{T}_C \approx 1.8 * 10^{-12} \text{ secs.}$$

The target electron moves a distance Δz_k as a result of this its k^{th} (return) interaction, where: $\Delta z_k = V_k \Delta t_k$. Here, Δt_k is the time difference between its k^{th} impulse and its $(k+1)^{st}$ impulse received at the target electron.

$$z_{n+1} = z_0 + \Sigma^n \Delta z_k = z_0 + \Sigma^n V_k \Delta t_k = z_0 + b \sin\phi\, \Delta t_1 \Sigma^n k^2 = z_0 + n(n+1)(2n+1)\, b \sin\phi\, \Delta t_1 / 6$$

Using the Compton wavelength λ_C (introduced in 6.2.2 and $\Lambda_0 = c\,\tau$) then: $z_{n+1} = n(n+1)(2n+1)\Lambda_0 N_0 (\pi/\alpha)/6\surd 2 + z_0$

For $n = N - 1$ then: $z_N = Z_0$ (and as, $Z_0 >> z_0$), so: $Z_0 \approx (N-1)(2N-1)\Lambda N_0(\pi/\alpha)/6\surd 2$ or $Z_0 \approx N_0^3 \lambda_C / 3$

$$t_{n+1} = t_0 + \Sigma^n \Delta t_k = \mathcal{T}_0 + \Delta t_1 \Sigma^n k = t_0 + \Delta t_1 \Sigma^n k^2 = t_0 + n(n+1)(\pi/\alpha) N_0^2 \tau / 2 \quad .$$

Again, for $n = N - 1$ with $\mathcal{T} \equiv t_N - t_0$ so: $\mathcal{T} \approx N(N-1) N_0^2 \mathcal{T}_C / 4$ or $\mathcal{T} \approx N_0^4 \mathcal{T}_C / 4$

$$\therefore\ X_0 = Z_0 \approx 6 \times 10^{16}\ \text{cm} \approx 1/15\ \text{LYr} \quad \& \quad \mathcal{T} \approx N_0^4 \mathcal{T}_C / 4 \approx 5.4 \times 10^{15}\ \text{sec.} \approx 1.75 \times 10^8\ \text{Yrs}$$

These numbers are so large that it suggests that it is **rare** for two electrons to complete a full set of interactions together; it is much more probable that either electron will participate in other interactions with third-party (other) electrons first.

Non-Relativistic Motion

When each electron is near the 'mid-point' M of their trajectory ($n = n' = N/2 \equiv M$) they are moving in the same direction with similar (absolute) speeds of $c/2$, so that their relative motion is almost zero; i.e. the **non-relativistic** region.

Around the 'mid-point' (M) $n = M \pm k \therefore \Delta t_k = \mathcal{T}_C N^2 / 4\, |(k-1| \therefore \Delta t_M = \mathcal{T}_C N^2/4 = \mathcal{T}_C N_0^2/2 \approx 2 \times 10^{-3}$ secs.

Thus, electron #1 spends the majority of its transit time around the mid-point region when the time between interactions, Δt_k is about a billion times longer than when it is moving near its extrema (Δt_1 and Δt_N). Since the electron's speed difference is only a factor of two between these event zones then this electron covers the largest spatial extent in the mid-point region. The complete travel time for each electron during each phase is: $T_0 = T_N$, where:

$$T_N = \sum_{n=1}^{n=N/2} \Delta t_n = \mathcal{T}_C N^2 / 4 \sum_{n=1}^{n=N/2} 1/(2n-1) = \mathcal{T}_C N^2/4 \sum_{n=1}^{n=N/2} 1/n = \mathcal{H}_{N/2}\, \mathcal{T}_C N^2/4 \approx \ln[N/2]\, \mathcal{T}_C N^2/4$$

Here, $\mathcal{H}_N$ is the '**Harmonic**' function (or N^{th} harmonic number), which is the sum of the inverse integers from 1 to N. It is very well approximated by the natural logarithm for N larger than 1000, whereas here: $N = N_0 \surd 2 \approx 2.33 \times 10^9$

$$\therefore\ T_0 \approx 8.16 * 10^{-2}\ \text{secs} \approx 20 \times \Delta t_{N/2}$$

Thus, each electron spends most of its journey around the 20 or so mid-point events where its speed is close to $c/\surd 2$ so that the maximum longitudinal distance traveled by each electron during either phase is approximately: $Z_0 \approx 8.6 \times 10^8$ cm.

In electron #1's inward phase the x-z roles are reversed: $\therefore\ \underline{V}_j = [-(N-j)\,\underline{\hat{e}}_3 + j\,\underline{\hat{e}}_1]\, c/N \quad [1 \le j \le N]$

Total Momentum

Returning now to the explicit *Asymmetric Temporal* labeling scheme then it can be readily seen that the velocity of electron #2 participating in the $(N+j)^{th}$ interaction is $\underline{V}'_{N+j}$ combining with electron #1 to form the total two-electron velocity $\underline{V}_T$.

$$\therefore\ \underline{V}'_{N+j} = \underline{U}'_{N+j} + \underline{W}'_{N+j} = \underline{U}_{2N-j} + \underline{W}_{2N-j} = \underline{V}_{2N-j} = [(N-j)\,\underline{\hat{e}}_3 + j\,\underline{\hat{e}}_1]\, c/N$$

$$\therefore\ \underline{V}_T = \underline{V}_{N+j} + \underline{V}'_{N+j} = (\underline{\hat{e}}_3 + \underline{\hat{e}}_1)\, c \quad \therefore\ \underline{\hat{e}}_3 \bullet \underline{V}_T = c \quad \& \quad \underline{\hat{e}}_1 \bullet \underline{V}_T = c \quad \text{which is constant.}$$

$$\therefore\ (\underline{V}'_{N+j})^2 = [j^2 + (N-j)^2]\,(c/N)^2 = (V_j)^2 \quad \therefore\ \mathcal{K}'_{N+j} = \mathcal{K}_{N+j} \quad \therefore\ \Delta\mathcal{K}'_{N+j-1} = \Delta\mathcal{K}_{N+j-1} \quad \therefore\ \Delta t'_{N+j} = \Delta t_{N+j}$$

Complete Trajectories

Here, the **trajectories** of the two electrons are designated by solid arrows moving in straight lines from node to node while the dashed lines represent each <u>interaction</u> between the two electrons experienced as <u>impulses</u> represented by double arrows.

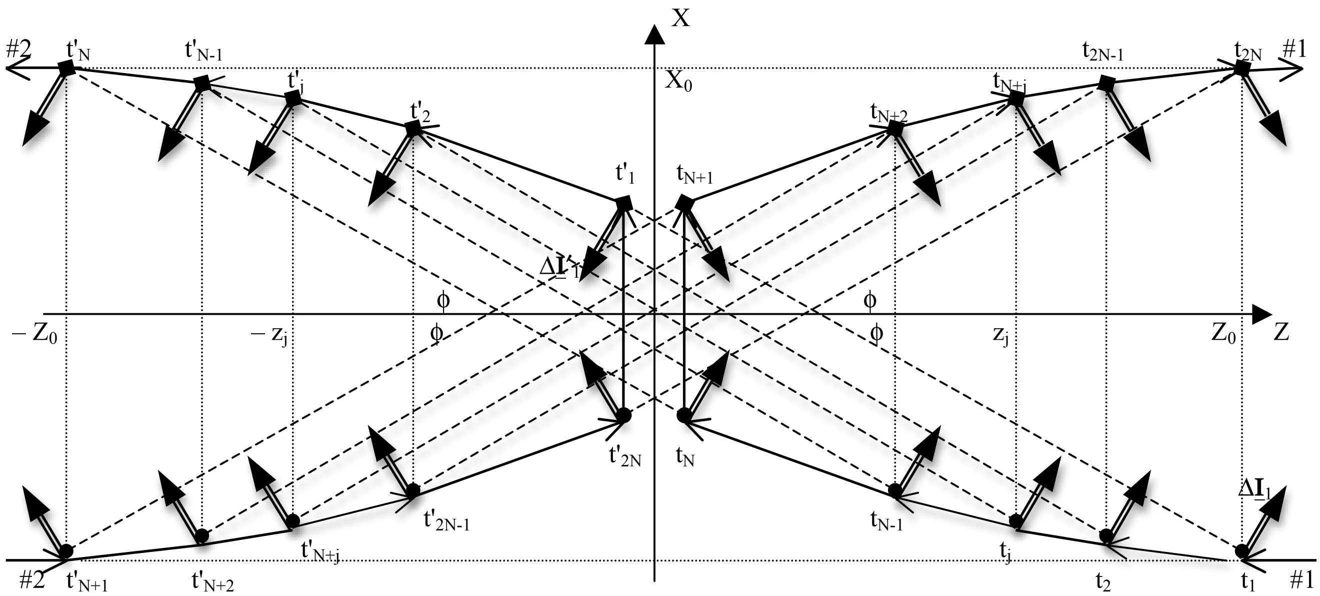


Fig. 7 Complete Remote 2D Repulsive Interaction Schematic.

The diagram illustrates the two electrons initially approaching each other 'head-on' at 'light-speed' c at times less than $-T_0$ at a distance X_0 parallel to the z-axis but are too far apart (in space and time) to have any interaction until each electron is only at the location $+x_0$ from the origin at a time $+t_0$. The best way to view this diagram (where time is implicit) is to track the events of electron #1 through its own local time. At time t_1 electron #1 initiates an interaction by experiencing the EM impulse, $\Delta\underline{\mathbf{I}}_1$ such that electron #2 experiences the complementary impulse, $\Delta\underline{\mathbf{I}}'_1$ at the later time, t'_1. Electron #1 has its velocity altered by the impulse $\Delta\underline{\mathbf{I}}_1$ from $\underline{V}_0 = -c\,\underline{\hat{e}}_3$ to $\underline{V}_1$ while electron #2 has its own velocity altered by the impulse $\Delta\underline{\mathbf{I}}'_1$ from $\underline{V}'_{2N} = W_0\,\underline{\hat{e}}_1$ to $\underline{V}'_1$. The motion is qualitatively sensitive to the initial value Z_0.

This process is repeated for the interactions labeled j = 2 through N when at time t_N electron #1 reaches the closest distance to the origin $[x_N = x_0 ; z_N = z_0]$ where, *by design*, its velocity in the z-direction is **zero** but its velocity in the x-direction is not zero, i.e. $\underline{V}_N = W_0\,\underline{\hat{e}}_1$. During the next interval of duration $2\,t_0$ electron #1 crosses the z-axis until at time t_{N+1} it then undergoes its next interaction; this is followed by another N-1 interactions until at time t_{2N} electron #1 reacts to its last and final impulse, $\Delta\underline{\mathbf{I}}_{2N}$; this brings its velocity up to 'light-speed' again, i.e. $\underline{V}_{2N} = +c\,\underline{\hat{e}}_3$. Afterwards, it is beyond range. Both event sets increase monotonically from: $t_1 = -T_0$ through $t_N = -t_0$ and $t_{N+1} = +t_0$ to $t_{2N} = +T_0$ while the special labeling means that: $t'_{N+1} = -T_0$ through $t'_{2N} = -t_0$ and $t'_1 = +t_0$ to $t'_1 = +T_0$ $\therefore$ $t'_j = t_{N+j}$ & $t'_{N+j} = t_j$ $[1 \le j \le N]$.

6.2.6 THE 3D TWO-ELECTRON SYSTEM

Direction Labeling

The analysis of the two dimensional model of a complete set of interactions between two electrons completed above was based on selecting an arbitrary transverse direction (labeled x) with its own corresponding interaction angle ϕ. This can be made explicit by adding an identifying subscript (x), where:

$$\tan \phi_x = X_0 / Z_0$$

Another direction (y) may be introduced with its own extremal offset difference Y_0 : $\tan \phi_y = Y_0 / Z_0$

The complete 2D analysis could have been done in this second direction and the results would remain unchanged. These two may be combined, as long as they share the same longitudinal initial offset Z_0. This implies that the full 3D scattering model for two electrons still demonstrates **parabolic** trajectories in each of the two transverse directions, with the electrons crossing the z-axis at the same moment in both directions. This is the physical model of optical effects that has been described in terms of fluctuations in the values of the mathematical quantity known as the electromagnetic field (classical EM) or a radiation particle ("photon") with two degrees of freedom in the transverse direction. Unfortunately, neither of these earlier models has ever found their mathematical symbols correspond to anything in reality. They have simply played the roles of mathematical intermediaries that disappear at the conclusion of the calculations.

6.3 MANY-ELECTRON INTERACTIONS

All of the previous papers in this series have focused on only two electrons – this was because it was necessary to achieve a deeper understanding of the basic interaction between **two** electrons. However, the real world certainly contains more than two electrons. Even if the universe is infinite in extent, there can never be an infinite number of discrete electrons within any finite region, no matter how large that region is defined. So, it is now time to extend the present theory to a more realistic view of the micro world, particularly one that is subject to human experimentation. Under laboratory conditions, the extent of the experimental region is always relatively small – a few meters in each direction, so finite results must be expected.

6.3.1 INFORMATION & CHOICE

Localization

Although nature must ultimately be viewed as one integrated holon, the presence of complexity implies that localization is still important; i.e. effects generated by interactions between parts diminish with distance, otherwise the universe would be too tightly coupled into a single, simple unity: a really boring 'Big Ball'. This is reflected here in the impulse model of the interaction, which was studied extensively in the previous paper [158]. Furthermore, the finite 'speed of light' is necessary, otherwise all the electrons in the universe would again be too tightly coupled together across time, acting again as a singular entity. The finite time differences mean that interactions between near-local collections of electrons will dominate with the result that the universe exhibits more **diversity** and **complexit**y. This is reflected in the present theory through the basic 'light-cone' condition.

There are only two basic ways to change the relative positions of the material components of the universe: either an electron can change its own position over an interval of time (inertial movement) or two electrons interact and change their relative velocities (asynchronous action-at-a-distance). These two methods can be combined, generating a real material medium.

1) $A[t_1] \rightarrow A[t_2]$ 2) $A[t_1] \Rightarrow B[t_2]$ 3) $A[t_1] \Rightarrow B[t_2] \Rightarrow C[t_3]$

Informed Decisions

This theory is fundamentally about interactions and information. Each time an electron participates in an interaction, it needs to know *the when and the where* of its partner in this transaction making this is an inherently **non-local** theory. It is possible that the total action of all electrons is minimized over an extended time-scale. Momentum is always conserved across each **complete** interaction but **not** at all times in between (contrary to the Helmholtz continuous energy *hypothesis*). Energy is only conserved in individual attractive interactions or across several, consecutive and completed interactions.

Information

The introduction of interaction-selection at the level of pairs of electrons introduces the concept of *information* explicitly into the foundations of physics. At each interaction point, in every electron's chronon cycle, the electron must determine which other electron in the universe will be selected for participating in a possible interaction. This has never been a problem when physics simplified the world by making interactions continuous at *all* times and universal between *all* other electrons.

The idea of ***information*** has become a powerful and central concept in the modern world. Unfortunately, it has developed multiple meanings and associations. In its most general sense, information is any kind of real **event** that informs a dynamic system of changes in its context that can affect its state. Information can thus be used to predict causal changes. It has been suggested that information is always the answer to a specific question; in this special case: "which electron will be my next partner?" In this form, interaction-selection is the most basic decision made in the evolution of the universe – it resolves the fundamental **uncertainty** (at the level of the electron) of what happens next. It is important to understand that the use of this concept in this <u>material</u> theory is <u>not</u> part of the post-modern view that "*physics is now synonymous with information*". [166]

In its human usage, information is associated with the idea of an ordered sequence of symbols forming messages that can be interpreted by a suitably informed recipient. Developments in biochemistry (e.g. DNA) have demonstrated that information is critical in systems much smaller than human brains (e.g. cells). It is in this sense that the idea of information is introduced into the present theory, as it is the knowledge of a **spatiotemporal** pattern that influences the formation or transformation of other patterns; in this case, a subsequent exchange of momentum between electron pairs through specific interactions. Gregory Bateson was right to define information [167] as the "*difference that makes a difference*".

Electrons have Universal 'Awareness'

Maxwell's formulation of Newton's Second Law of Motion highlights the unstated assumption of classical physics that the change in the system's momentum during any time interval is measured by the vector sum of the impulses generated by all the external forces [168] during this interval. The challenge to this fundamental assumption is at the heart of this theory of the electron. In classical EM, every charged particle '**knew**' about every other charged particle in the universe and would interact continuously with **all** of them that were on its historic light-cone (retarded potentials). In contrast, in this EM theory, every electron 'knows' about the location of every other electron everywhere and at all times (past and future) in order to **select** one (at every possible interaction point) with which it will interact. Once selected its 'sent' impulse behaves like a letter mailed to a uniquely addressed individual while in CEM, which is a 'broadcast' theory, the charge responds to all the shouts received from everyone on the planet within earshot (that actually extends to infinity). Consciousness is the awareness of a real situation combined with the possibility of changing the situation; i.e. interacting. Electrons, at each chronon, are aware of the location (and thus local motion) of every other electron in the universe and may choose to interact with one of them. As collections grow in number (nuclei, atoms, molecules, cells, etc.) more and more of their interactions become **internal** (highly localized), to the point where humans can now construct symbolic representations (through images and language) of the external world; these representations (information) become shareable between people.

Some people will reject the present theory on the grounds that only humans can exhibit consciousness. This is an existential assumption and it cannot be argued against on intellectual grounds but only **experientially**. If this theory provides a better description of reality, as perceived by human beings, then its assumptions and hypotheses must be given greater credence, no matter if they challenge long held beliefs on the nature of reality – this has always been the basis for progress in physics.

6.3.2 SELECTION OVERVIEW

Two-phase Interaction Cycle

This section will present a detailed mechanism for how two electrons decide if they will exchange momentum at their next interaction times. This will show that the basic idea of a two-phase, cyclic interaction (previously used to define when real momentum is exchanged) can be extended to the idea of exchange of necessary information on each partner's place in space and time, its direction of interaction in space (i.e. charge) and the direction of interaction in time (retarded or advanced). So, in this new model an electron decides on its next partner (**selection** or information phase) and then a momentum changing impulse is exchanged (**action** phase). The selection phase itself consists of a **query** stage followed by an **answer** stage.

Only Serial Interactions

The **saturation** hypothesis forbids multiple impulses being experienced by a single electron at any instant; hence, multiple interactions with any particular electron must be experienced serially over time with the resulting changes in momentum being compounded additively over the short time duration (semi-period) of the composite set of serial interactions.

Spherical Interaction only on Selection

All interactions throughout the history of physics have been assumed to act continuously (**forces**) and all forces originating from a point in space have been assumed to act isotropically – physics has exhibited a long-term fascination with spherically, symmetric forces. Gilbert **Lewis** was one of the few scientists to reject the assumption of spherical symmetry [169]. In 1926, he even dared to challenge the universally held view that EM effects were generated locally and then radiated equally in all directions into the cosmos (i.e. '*broadcast*') where they would travel until they 'accidentally' hit other charged particles that eventually absorbed all the initial energy of radiation. He proposed the model used **herein** where EM energy is transmitted between just two "atoms", where both source and absorber play symmetrical parts in the exchange process. Mead actually ends his magnificent little book with this story and regrets (as we do) that this key insight was immediately ignored [170]. In the present theory, the possibility of interaction is assumed *isotropic* in direction but every actual interaction is always **ray-like**. Therefore, the EM impulse is statistically spherically symmetric with respect to distant electrons, when averaged over many chronons but this is not so, when other electrons are 'near' when stable, cyclic trajectories are favored. Once the optimum interaction-partner electron has been identified then the act of interaction (i.e. the impulse) is always ray-like with the selected partner electron, so that only one direction in space is selected per chronon ($\Delta \underline{p} \rightarrow \underline{\hat{e}}$). When this is repeated serially between the same two electrons this same, interaction direction is maintained and corresponds to the axis of the familiar wave-vector, $\underline{k} = k\,\underline{\hat{e}}$. Lewis and Mead are two of the intellectual forefathers of UET.

6.3.3 INTERACTION SELECTION RULES

Interaction Conditions

One of the major hypotheses forming the foundation of this research programme is that the EM interaction is **saturated** – this means that when an electron interacts at a given time, it only interacts with **one** other electron at that time – each interaction only occurs between pairs of electrons and not between all charged particles. The fundamental proposal in this theory is the rejection of continuous interactions between all electrons.

The key chronon hypothesis leads to the idea that electrons may only interact **periodically** when they may send or receive impulses. These ideas combine to create a set of Interaction Conditions that define when any two electrons may interact. Two electrons **may** only interact together at their respective possible interaction times t_n (#1) and t'_n (#2) if they satisfy **all** the following conditions.

1) The two electrons are on each other's light-cones at these two times (see §6.1.2).

2) One electron is in its 'snd' phase while the other is in its 'rcv' phase [171].

3) If $t_n < t'_n$ and electron #1 is in its retarded 'snd' phase then electron #2 must be in its retarded 'rcv' phase, or electron #1 is in its advanced 'rcv' phase and electron #2 must be in its advanced 'snd' phase.

4) If $t_n > t'_n$ and electron #2 will 'snd' into its future and electron #1 will 'rcv' from its past (retarded) or electron #2 will 'rcv' from its future and electron #1 will 'snd' into its past (advanced).

5) Neither electron has **yet** committed to participate in an interaction at these two times.

Interaction Roles

In hypothesizing that the interaction between electrons is saturated (i.e. never occurs between more than two electrons) the "selection rules" for which pairs of electrons 'partner-up' become central to the dynamics of any collection of three or more electrons. Only in ideal or abstract situations, will there ever be only two electrons under consideration. Thus, when a given electron [labeled 'j' and referred to as the *target*, exhibiting positive or negative electric charge q_j ($\pm e$)], is at a point in time t_j in its cycle, it is ready to commit to participating in an interaction. It will exchange information with a subset of other electrons (labeled by the set {'k'} and referred to as the *candidates*). Each complies with the interaction conditions (6.2.2). As there will usually be more than one candidate possible in any cycle, one of them will usually be selected when it will be referred to as the *partner* electron of the target. There are certain situations that may arise when some (perhaps, all) of the candidates may be eliminated from selection; these situations are referred to as *forbidden selections*. When there are still two or more viable candidates, the selected partner electron in the interaction is chosen based on the *Optimization Rule*.

Forbidden Selections

An electron at [t ; $\underline{x}$] **never** interacts with another electron at [t′ ; $\underline{x}'$], even when both electrons are at multiples of their own chronon cycle and both are on each other's light-cones, whenever their relative (line-of-sight) velocity **exceeds** light speed.

There is also **no** interaction when two other electrons, at locations [t_1 ; $\underline{x}_1$] and [t_2 ; $\underline{x}_2$], are 'candidate partners' with **equal light-cone** separations; i.e. if:

$$|\,(\underline{x}_1 - \underline{x})\,| = |\,(\underline{x}_2 - \underline{x})\,| \quad \text{and} \quad |\,(t_1 - t)\,| = |\,(t_2 - t)\,|$$

The symmetry of space suggests that when two or more possible 'candidate' electrons are exactly the same distance from the source or target electron then **none** of them is selected and other electrons must be considered as possible 'partners' for each of the original three (or more) electrons. In these situations, there is no way to distinguish each of the possible choices – there is just too much symmetry to be 'broken'.

6.3.4 THREE-ELECTRON SELECTION

The first occurrence of selection arises in situations involving three electrons (this will be seen as the technique for cutting the Gordian Knot of the **3-body** problem that has confounded the physics of continuous forces since Newton's day). At any possible interaction time t_n for a given electron (say #1) the choice arises: does this electron interact with electron #2 or electron #3? If only one of these two other electrons satisfies the Interaction Conditions with electron #1 (see §6.1.5) then this will be the interaction of electron #1 selected for at time t_n.

Unlike continuum physics, all interactions are never viewed as coincident in time at the target electron but can be sequential. For example, in classical physics, with its **instantaneous** interactions, there are always combined interactions with the target electron (say, #1) from two remote particles (labeled #2 and #3). Let the interaction at time t between the pair of particles labeled j and k be designated $I_{jk}[t]$ and the actual impulse experienced by particle j at time be designated as $I_j[t]$ then:

Classical mechanics allows: $I_1[t] = I_{12}[t] + I_{13}[t]$ (i.e. **AND**) But now only: $I_1[t] = I_{12}[t]$ **or** $I_{13}[t]$ but **not both**.

There are no instantaneous or static interactions, like the Coulomb 'force' with its cumulative summation of potentials. In effect, the quantized EM interaction introduces a logical 'exclusive or' (XOR) while classical physics deals with the simpler, logical 'non-exclusive or' (OR). The resulting logical consequences can then be radically different. It will be shown in the next paper that this difference (XOR rather than OR) explains the non-commutivity of quantum mechanics and the failure of simple algebra to form a suitable representation for the micro-dynamics exhibited by electrons at the atomic scale

3-Electron Forbidden Selections

The target electron in a triplet situation will not interact with either of the other two electrons under the following conditions.

A) If the other two electrons have already selected each other then electron #1 will not select either of these other two at this time.

B) If the other two electrons are both equally selectable and are both situated equidistant from electron #1.

These rules are illustrated in the following diagrams.

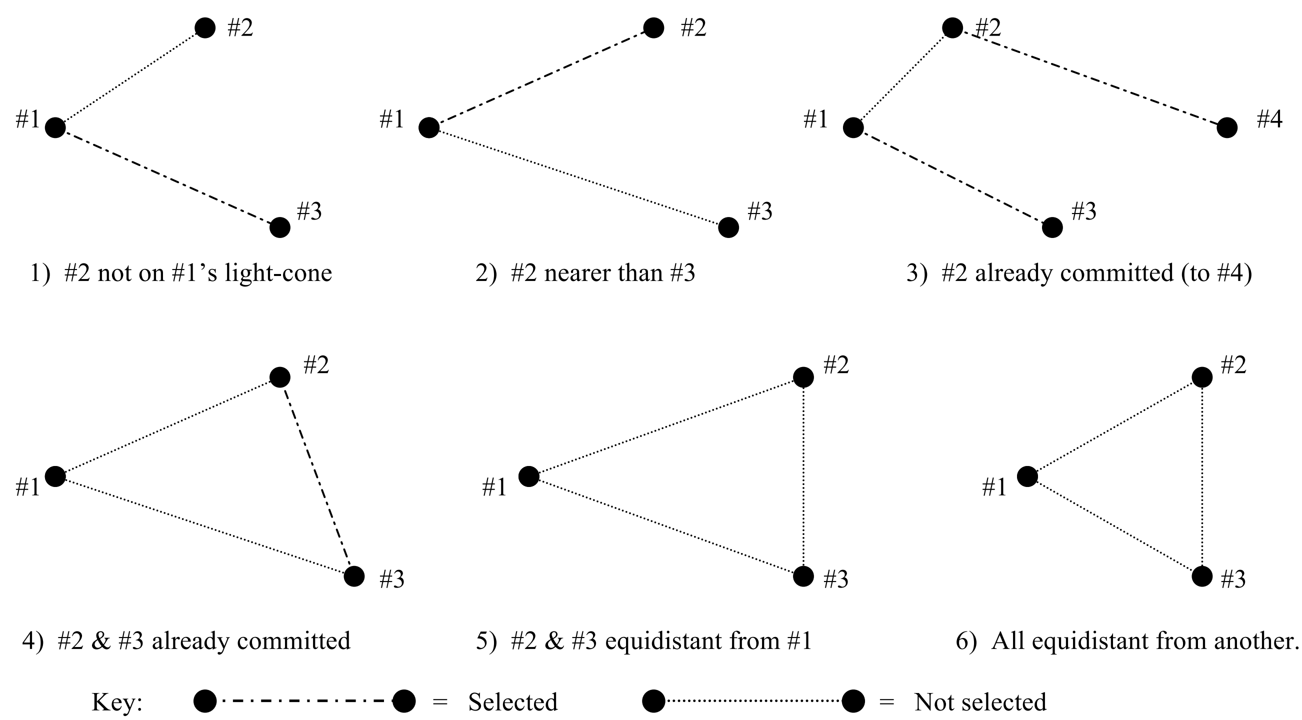


Fig. 8 Three-electron Selections

6.3.5 THE SELECTION MECHANISM

Overview

In order for two electrons to commit to an exchange of momentum at their next interaction points, it is necessary to **know** the identity of the other electron, where it is located (distance and direction), its temporal 'direction' (past or future) and whether the interaction is attractive or repulsive (relative charge). All of this is information that must be made available to each of the electrons in the pending interaction. The proposed mechanism requires an *information wave* to be emitted from each suitable electron across the universe that is reflected back from each candidate electron that satisfies the Interaction Conditions (see §6.1.5). The emitter then selects one (or zero) of these candidates and 'emits' a real momentum impulse to the winning candidate – if there is one, in this cycle; the cycle then repeats. The binary choice resulting from this selection process contributes to the digital view of the universe presented in this theory. An analogy of this process might be sending out invitations one morning via a social media network and later responding to one of the replies to establish a dinner-date for the upcoming evening. It will be noticed that this is a more detailed mechanism than Wheeler and Feynman's reflecting-absorber model that only used EM fields (or potentials) for the 'wave' mechanism (see §5.2.1) but it does share the critical feature of combining wave transmissions **both** forwards and backwards across time. This is a scalar/vector model combining a 'broadcast' with a 'ray' model during the Selection phase, whereas in the Action phase the momentum exchange is a pure directed (ray-like) response back along the direction of the selected 'answer'. It is not a coincidence that this selection model bares more than a passing resemblance to John Cramer's transaction interpretation of quantum mechanics. [171]

The information wave emitted in the first half of the Selection phase is referred to as the **Q***uery* wave while the information wave emitted in the second half of the Selection phase is referred to as the **A***nswe*r wave. It is herewith proposed that these information waves travel at light-speed *c* across all of space and it will be shown that when they both propagate spherically in 3D space they satisfy the principle of least time, so they will always be considered as outwardly expanding spherical waves. The key idea here is that these two waves travel in complementary directions with respect to time; if the Q-wave travels forwards through time (retarded) then the A-wave travels backwards in time (advanced) while if the Q-wave travels backwards through time (advanced) then the A-wave travels forwards in time (retarded). The mechanism of selection still respects the idea that interactions are limited by the speed of light but the two-way exchange of **information** (forwards and backwards across time) achieves essentially an **infinite** scan of the universe in two chronons of time (see later). The next diagram illustrates one ***complete*** interaction cycle between two electrons (the target #1) and (eventually) the partner (#2). At time t_1 at location $\underline{x}_1$ the target electron emits its Q-wave that is received by electron #2 at time t_2 at location $\underline{x}_2$ then at time t'_2 at location $\underline{x}'_2$ the candidate electron emits an A-wave that is received by electron #1 at time t'_1 at location $\underline{x}'_1$. Finally, at time t_n at location $\underline{x}_n$ the target electron sends a real impulse $\Delta\underline{\mathbf{I}}_n$ that is received by electron #2 at time t'_n at location $\underline{x}'_n$. Prior to the momentum exchange (at t_n) the target electron is moving with velocity $\underline{v}_{n-1}$ while the partner electron is moving at velocity $\underline{v}'_{n-1}$; after the completion of the momentum exchange, the target electron is moving with velocity $\underline{v}_n$ while the partner electron is moving at velocity $\underline{v}'_n$. Note: all electrons only move forwards through time.

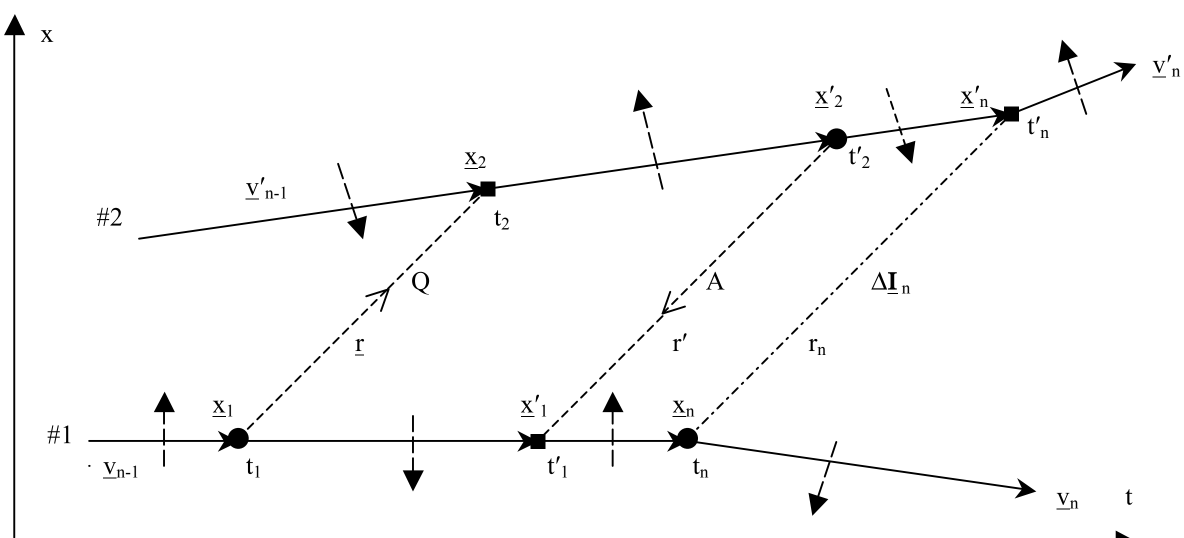


Fig. 9 The Complete Interaction Cycle

Query Stage

In the first half of the Selection phase (referred to here as the Query stage), the target electron (labeled α) is just about to exit its 'snd' phase (either retarded or advanced) when it emits a query wave at time t_1 from location $\underline{x}_1$. In order to distinguish this wave from all the other waves emitted by all the other electrons in the universe it could be uniquely labeled with its source identifier (i.e. α). However, at any interaction point, no two electrons may ever occupy the same location in space ($\underline{x}_n$) at the same interaction time (t_n), which must always be an integer multiple n of the chronon τ. These two real parameters (i.e. $\underline{x}_n$, t_n) can thus be used to distinguish this particular wave from all the other Q-waves emitted by all other electrons **and** by <u>this</u> electron throughout its eternal existence. It is also useful to denote the temporal direction of this wave at this time by σ_n, where: σ_n = 'ret' (or -) or 'adv' (or +). Symbolically, therefore this Q-wave is represented throughout all of space at every location $\underline{x}$ at a time t by the continuous function $\Phi_Q[\sigma_n, \underline{x}_1, t_1 ; \underline{x}, t]$. Specifically, in the case of a retarded Q-wave, the outgoing Q-wave is defined for all times $t > t_1$ and at spatial locations on a sphere at a distance r from $\underline{x}_1$ where $r = c\,(t - t_1)$. In the case of an advanced Q-wave, the outgoing Q-wave is defined for all times $t < t_1$ and at spatial locations on a sphere at a distance r from $\underline{x}_1$ where $r = c\,(t_1 - t)$; in both cases: $\underline{x} - \underline{x}_1 = \underline{r}$. As spherical waves, they satisfy the equation:

$$\Phi_Q[\sigma_n, \underline{x}_1, t_1 ; \underline{x}, t] = \exp[\, i\,(\kappa_0\, r + \sigma_n\, \omega_0\, (t - t_1))]\, \Phi^0{}_Q[\sigma_n, \underline{x}_1, t_1] / r \quad \text{where: } \kappa_0 = 2\pi / \Lambda \;,\; \omega_0 = 2\pi / \tau \;,\; \Lambda = c\,\tau$$

Answer Stage

In the second half of the Selection phase (referred to here as the Answer stage), any candidate electron must be just about to exit its 'rcv' phase when its 'absorbs' the Query wave from the target electron and then enters its next 'snd' phase. If this candidate electron (at $\underline{x}_2$, t_2) finds that it has received two or more Q-waves then it ignores all of them. However, if it only receives one Q-wave at this time then it emits its own Answer-wave at time t'_2 from the spatial location $\underline{x}'_2$. By design, all A-waves are in the reverse time direction from the previously received Q-wave, so that the A-wave's temporal response direction $\sigma'_n = -\sigma_n$. Therefore, symbolically, this A-wave is represented throughout all of space at every location $\underline{x}$ at a time t by the continuous function $\Phi_A[\sigma'_n, \underline{x}'_2, t'_2 ; \underline{x}, t]$. Again, in the case of a retarded A-wave, the outgoing A-wave is defined for all times $t > t'_2$ and at spatial locations on a sphere at a distance r′ from $\underline{x}'_2$ where $r' = c\,(t - t'_2)$. In the case of an advanced A-wave, the outgoing A-wave is defined for all times $t < t'_2$ and at spatial locations on a sphere at a distance r′ from $\underline{x}_n$ where $r' = c\,(t'_2 - t)$; in both cases: $\underline{x} - \underline{x}'_2 = \underline{r}'$. Since these are also spherical waves, they satisfy:

$$\Phi_A[\sigma'_n, \underline{x}'_2, t'_2 ; \underline{x}, t] = \exp[-\, i\,(\kappa_0\, r' + \sigma'_n\, \omega_0\, (t - t'_2))]\, \Phi^0{}_A[\sigma'_n, \underline{x}'_2, t'_2] / r'$$

The A-wave's exponent introduces a negative sign but these factors are arbitrary (as long as they are opposite).
The initial amplitude of the A-wave $\Phi^0{}_A$ is chosen to be the value of the Q-wave's amplitude Φ_Q when it was 'absorbed' at position $[\underline{x}_2, t_2]$, so that it may be reflected back to the Q-wave's source from its next appropriate 'snd' position at $[\underline{x}'_2, t'_2]$.

$$\Phi^0{}_A[\sigma'_n, \underline{x}'_2, t'_2] \equiv \Phi^0{}_A[\sigma'_n, \underline{x}_2, t_2] = \Phi_Q[\sigma_n, \underline{x}_1, t_1 ; \underline{x}_2, t_2]$$

The final form of the information function Φ is chosen to be the value of the A-wave when it is absorbed back by the target electron when it is at its next appropriate 'rcv' point at time t'_1 when the target electron has reached the spatial location $\underline{x}'_1$.

$$\Phi[\sigma_n, \underline{x}_1, t_1 ; \underline{x}'_1, t'_1] \equiv \Phi_A[\sigma'_n, \underline{x}'_2, t'_2 ; \underline{x}'_1, t'_1]$$

Now, defining: $\underline{\kappa}_0 \equiv \kappa_0\,(\underline{x}_2 - \underline{x}_1) / |\,\underline{x}_2 - \underline{x}_1\,| \equiv \kappa_0\,(\underline{x}'_2 - \underline{x}'_1) / |\,\underline{x}'_2 - \underline{x}'_1\,| \quad \therefore\; \underline{\kappa}_0 \bullet (\underline{x}_2 - \underline{x}_1) = \kappa_0\, r \;\;\&\;\; \underline{\kappa}_0 \bullet (\underline{x}'_2 - \underline{x}'_1) = \kappa_0\, r'$

$$\therefore\; \Phi[\sigma_n, \underline{x}_1, t_1 ; \underline{x}'_1, t'_1] = \exp[-\, i\, \sigma_n\, \omega_0\, [(t'_2 - t_2) - (t'_1 - t_1)]]\, \exp[-\, i\, \underline{\kappa}_0 \bullet [(\underline{x}'_2 - \underline{x}_2) - (\underline{x}'_1 - \underline{x}_1)]]\, \Phi^0{}_Q[\sigma_n, \underline{x}_1, t_1] / r\, r'$$

Each of the electrons is undergoing **inertial** motion throughout these times; i.e. #1: $t_1 \to t'_1 \to t_n$ & #2: $t_2 \to t'_2 \to t'_n$

$$\therefore\; (\underline{x}'_1 - \underline{x}_1) = \underline{v}_{n-1}\, (t'_1 - t_1) \;\;\&\;\; (\underline{x}'_2 - \underline{x}_2) = \underline{v}'_{n-1}\, (t'_2 - t_2) \quad \text{while} \quad \omega_0 = c\, \kappa_0$$

$$\therefore\; \Phi[\sigma_n, \underline{x}_1, t_1 ; \underline{x}'_1, t'_1] = \exp[\, i\, [\underline{\kappa}_0 \bullet \underline{v}_{n-1} + \sigma_n\, c\, \kappa_0]\, (t'_1 - t_1)]\, \exp[-\, i\, [\underline{\kappa}_0 \bullet \underline{v}'_{n-1} + \sigma_n\, c\, \kappa_0]\, (t'_2 - t_2)]\, \Phi^0{}_Q[\sigma_n, \underline{x}_1, t_1] / r\, r'$$

The Fundamental Phase Cycles

In order to proceed further, it is necessary to recall the fundamental phase cycles [172] that deeply characterize the electron and the **positron** – these were first introduced in the previous paper. The basic idea is that all electrons (negative and positive) cycle around their 4 possible phase states identified by the phase variable 'ν', which corresponds to specific combinations of the binary 'snd' or 'rcv' variable 'λ' and the binary interaction temporal direction variable 'σ'; in other words: $\nu \equiv \lambda \otimes \sigma$. The transitions between these states define when the four possible inter-electron interactions can occur. Thus, every electron exits the state $|\nu\rangle$ and enters the next $|\nu + 1\rangle$ (modulo 4) at times t_ν. These times are all one chronon τ apart but the positron interaction times are all **one-half** chronon later; this offset was shown to be sufficient to account for the oldest observation concerning electricity: opposite charges attract, similar charges repel. [173]

The canonical phase representation was introduced in the previous paper [174] for assigning specific values of ν (in the range 1, 2, 3, 4) to a unique sequence of λ and σ values (each usually represented as ± 1) but sometimes explicitly as ($\uparrow$, $\downarrow$) and (ret, adv) respectively. In the present theory, both electrons and positrons cycle forever, always in phase, through the same four states but in two different sequences. The convention is that at time zero all electrons are in the first phase. Three equivalent notations are used to represent the phase states of electrons and positrons: the first uses the standard notation for these particles ($e^\pm$) with a subscript α to distinguish the two particles ('1' and '2') involved in an interaction and a phase state variable ν. The second notation extends the 'ket-style' vector-like notation introduced then [175] to include the particle's charge Q ($\pm e$); the third representation retains the interaction variables: 'S' for 'snd' and 'R' for 'rcv'.

Thus, $e^Q_\alpha(t_\alpha ; \nu) \approx |\, \alpha : t_\alpha :: \lambda , \sigma , Q \rangle$ with: $|\, \alpha : t_\alpha :: \uparrow , \sigma , Q \rangle \approx S^\sigma_\alpha(t ; Q)$ & $|\, \alpha : t_\alpha :: \downarrow , \sigma , Q \rangle \approx R^\sigma_\alpha(t ; Q)$

All electrons here have their initial phase ($\nu = 1$) occurring at times: $T^-_\alpha = 4 N_\alpha \tau$, with consecutive times for [ν = 2, 3, 4] at times [$(T^-_\alpha + \tau)$, $(T^-_\alpha + 2\tau)$, $(T^-_\alpha + 3\tau)$]. In order to accommodate the observed facts of electrical attraction or repulsion, it is necessary to propose that ***all the positrons are out-of-phase by one half chronon with all the electrons*** in the universe. Thus, the positrons initial phase here begins at times: $T^+_\alpha = (4 N_\alpha + \frac{1}{2})\tau$, with consecutive times for [ν = 2, 3, 4] at times [$(T^+_\alpha + \tau)$, $(T^+_\alpha + 2\tau)$, $(T^+_\alpha + 3\tau)$]. The electron was assigned the canonical sequence (1, 2, 3, 4) while the positron is now assigned the complementary (or reversed) sequence (1, 4, 3, 2). The following table will be useful in later discussions.

Time $\mathcal{T}_n$	1	2	3	4	5	6	7	8	9
e^- Phase	1	2	3	4	1	2	3	4	1
e^- State	S^-	R^+	S^+	R^-	S^-	R^+	S^+	R^-	S^-
e^+ State	S^-	R^-	S^+	R^+	S^-	R^-	S^+	R^+	S^-
e^+ Phase	1	4	3	2	1	4	3	2	1

Table 1. Electron & Positron Phase States

Therefore the electron times are : $\mathcal{T}^-_k = (4 N_\alpha + k - 1)\, \tau$ and the positron times are: $\mathcal{T}^+_k = (4 N_\alpha + k - \frac{1}{2})\, \tau$

NB The factor ½ that repeatedly reappears in relativistic formulations of QM.

The selection-times referred to in the last sub-section (t_1 & t'_1 and t_2 & t'_2) can now be related to the general interaction-times referred to here ($\mathcal{T}_n$ and $\mathcal{T}'_n$) as these must always follow t'_1 and t'_2.

Each interaction occurs between two particles: either, two electrons or two positrons or one electron and one positron; they will be symbolized as ($P_1 * P_2$); for example: ($e_1^- * e_2^+$), since experiments indicate this is based on the product of their charges. The fundamental physical hypothesis of the present theory is that interactions always involve the 'sending' of an interaction from one particle at one time (say, t_n) to the 'receiving' at the other particle at a different time (say, t'_n). Thus, there can be both retarded and advanced interactions $\Delta\underline{\mathbf{I}}^\pm$. [177]

Retarded Interaction: $\Delta\underline{\mathbf{I}}^-[1: t_n ; 2: t'_n] \cong \mathcal{S}^-[1: t_n]$ & $\mathcal{R}^-[2: t'_n]$ with $t'_n > t_n$

Advanced Interaction: $\Delta\underline{\mathbf{I}}^+[1: t_n ; 2: t'_n] \cong \mathcal{S}^+[1: t_n]$ & $\mathcal{R}^+[2: t'_n]$ with $t'_n < t_n$

where: $\Delta\underline{\mathbf{I}}_n^\sigma = -\lambda\, \Diamond[\, \underline{P}[1: t_n^- ; \underline{x}_n , \uparrow , \sigma]\,] = \lambda\, \Diamond[\, \underline{P}[2: t'^-_n ; \underline{x}'_n , \uparrow , -\sigma]\,]$ $(\lambda = \pm 1)$

The different types of interactions are summarized next (remembering that the 'adv' interaction occurs <u>backwards</u> in time).

A. $(e_1^- * e_2^-)$ ret: $\mathcal{S}^-[1: \mathcal{T}_1 ; e^-]$ & $\mathcal{R}^-[2: \mathcal{T}_4 ; e^-]$ adv: $\mathcal{S}^+[1: \mathcal{T}_3 ; e^-]$ & $\mathcal{R}^+[2: \mathcal{T}_2 ; e^-]$

B. $(e_1^+ * e_2^-)$ ret: $\mathcal{S}^-[1: \mathcal{T}_1 ; e^+]$ & $\mathcal{R}^-[2: \mathcal{T}_4 ; e^-]$ adv: $\mathcal{S}^+[1: \mathcal{T}_3 ; e^+]$ & $\mathcal{R}^+[2: \mathcal{T}_2 ; e^-]$

C. $(e_1^- * e_2^+)$ ret: $\mathcal{S}^-[1: \mathcal{T}_1 ; e^-]$ & $\mathcal{R}^-[2: \mathcal{T}_2 ; e^+]$ adv: $\mathcal{S}^+[1: \mathcal{T}_7 ; e^-]$ & $\mathcal{R}^+[2: \mathcal{T}_4 ; e^+]$

D. $(e_1^+ * e_2^+)$ ret: $\mathcal{S}^-[1: \mathcal{T}_1 ; e^+]$ & $\mathcal{R}^-[2: \mathcal{T}_2 ; e^+]$ adv: $\mathcal{S}^+[1: \mathcal{T}_7 ; e^+]$ & $\mathcal{R}^+[2: \mathcal{T}_4 ; e^+]$

In determining which part of the particle's phase cycle to use it must be remembered that the particle's first (information) event is of the same type as the particle's actual momentum (third) event while the intermediate (second information) event is their complement in both activity (snd/rcv) and temporality (σ); for example: $S^{\sigma}_{\alpha}\, R^{-\sigma}_{\alpha}\, S^{\sigma}_{\alpha}$ and $R^{\sigma}_{\alpha}\, S^{-\sigma}_{\alpha}\, R^{\sigma}_{\alpha}$ for particle α.

In evaluating the information function Φ, only time differences along the same particle's trajectory are significant, so the half-chronon offset for the positron becomes irrelevant but the nature of the particle playing each role (target or candidate) is still important as it determines which phase state must be used; this is illustrated in the next table.

Interaction	σ	E_1	E_2	t_n	t'_1	t_1	$t_n - t'_1$	$t'_1 - t_1$	t'_n	t'_2	t_2	$t'_n - t'_2$	$t'_2 - t_2$
$(e_1^- * e_2^-)$	ret:	$\mathcal{S}^-$	$\mathcal{R}^-$	$\mathcal{T}_5$	$\mathcal{T}_2$	$\mathcal{T}_1$	3τ	τ	$\mathcal{T}_8$	$\mathcal{T}_7$	$\mathcal{T}_4$	τ	3τ
$(e_1^- * e_2^-)$	adv	$\mathcal{S}^+$	$\mathcal{R}^+$	$\mathcal{T}_7$	$\mathcal{T}_4$	$\mathcal{T}_3$	3τ	τ	$\mathcal{T}_6$	$\mathcal{T}_5$	$\mathcal{T}_2$	τ	3τ
$(e_1^+ * e_2^-)$	ret:	$\mathcal{S}^-$	$\mathcal{R}^-$	$\mathcal{T}_5$	$\mathcal{T}_4$	$\mathcal{T}_1$	τ	3τ	$\mathcal{T}_8$	$\mathcal{T}_7$	$\mathcal{T}_4$	τ	3τ
$(e_1^+ * e_2^-)$	adv	$\mathcal{S}^+$	$\mathcal{R}^+$	$\mathcal{T}_7$	$\mathcal{T}_6$	$\mathcal{T}_3$	τ	3τ	$\mathcal{T}_6$	$\mathcal{T}_5$	$\mathcal{T}_2$	τ	3τ
$(e_1^- * e_2^+)$	ret:	$\mathcal{S}^-$	$\mathcal{R}^-$	$\mathcal{T}_5$	$\mathcal{T}_2$	$\mathcal{T}_1$	3τ	τ	$\mathcal{T}_6$	$\mathcal{T}_3$	$\mathcal{T}_2$	3τ	τ
$(e_1^- * e_2^+)$	adv	$\mathcal{S}^+$	$\mathcal{R}^+$	$\mathcal{T}_7$	$\mathcal{T}_4$	$\mathcal{T}_3$	3τ	τ	$\mathcal{T}_8$	$\mathcal{T}_5$	$\mathcal{T}_4$	3τ	τ
$(e_1^+ * e_2^+)$	ret:	$\mathcal{S}^-$	$\mathcal{R}^-$	$\mathcal{T}_5$	$\mathcal{T}_4$	$\mathcal{T}_1$	τ	3τ	$\mathcal{T}_6$	$\mathcal{T}_3$	$\mathcal{T}_2$	3τ	τ
$(e_1^+ * e_2^+)$	adv	$\mathcal{S}^+$	$\mathcal{R}^+$	$\mathcal{T}_7$	$\mathcal{T}_6$	$\mathcal{T}_3$	τ	3τ	$\mathcal{T}_8$	$\mathcal{T}_5$	$\mathcal{T}_4$	3τ	τ

Table 2. Electron & Positron Selection States

This table illustrates several regularities:

1) the temporal duration from the first event to the third event (e.g. $t_n - t_1$) is always 4τ (i.e. one full cycle);
2) when the information delay (e.g. $t_n - t'_1$) is 3τ then the momentum delay (e.g. $t'_1 - t_1$) is τ and vice-versa;
3) when the electron (e_1^-) is the partner then the information delay is always 3τ and for the positron (e_1^+) it is τ
4) the momentum delays are equal when the particles are oppositely charged (i.e. $t'_2 - t_2 = t'_1 - t_1$).

The explicit time factor in the information function Φ only involves the difference between the momentum delays; i.e. the phase factor $[(t'_2 - t_2) - (t'_1 - t_1)]$; this is zero when the particles are oppositely charged and has the value $\pm\, 2\tau$ when similar. This distinction enables the target particle to <u>determine</u> if the impulse is attractive or repulsive. Therefore, when any of these 'equal-charge' time values are substituted into the explicit time factor of the information function Φ they cancel out, since:

$$\exp[- i\, \sigma_n\, \omega_0\, [(t'_2 - t_2) - (t'_1 - t_1)]] = \exp[\pm\, i\, 2\, \sigma_n\, \omega_0\, \tau] = \exp[\pm\, i\, 4\, \pi\, \sigma_n] = 1$$

This leaves only the spatial differences, which involve the temporal differences implicitly through their inertial motion.

$$\exp[- i\underline{\kappa}_0 \bullet [(\underline{x}'_2 - \underline{x}_2) - (\underline{x}'_1 - \underline{x}_1)]] = \exp[- i\underline{\kappa}_0 \bullet [\underline{v}'_{n-1}\, (t'_2 - t_2) - \underline{v}_{n-1}\, (t'_1 - t_1)]] = \exp[\, i[(2 + q)\, \underline{v}_{n-1} - (2 + q')\, \underline{v}'_{n-1}] \bullet \underline{\kappa}_0\, \tau\,]$$

Thus, the information function Φ for two electrons with **charge** numbers **q** & **q′** (± 1) only depends on their <u>pre-interaction relative velocities</u> ($\underline{v}_{n-1}$ and $\underline{v}'_{n-1}$) and their <u>separations</u> (r and r′) and <u>independent of the temporality</u> of their interaction (σ_n).

$$\therefore\ \Phi[q, \underline{x}_1; q', \underline{x}'_1] = \exp[\, i\, [\, (2 + q)\, \underline{v}_{n-1} - (2 + q')\, \underline{v}'_{n-1}\,] \bullet \underline{\kappa}_0\, \tau\,]\, (c\, \tau)^2 / r\, r' \qquad \text{Normalizing: } \Phi^0_Q[\underline{x}_1, t_1] = (c\, \tau)^2$$

6.3.6 PLAYING IN THE SIRF

The information function Φ is quite general and is sufficient to determine the outcome of a single interaction between any two electrons (of either charge or whether retarded or advanced). The more interesting situations occur when the two particles interact many times together and consecutively, as in remote EM interactions or, even more so, when a pair of oppositely charged electrons interact together so often that they become a bound-state. In actuality, all bound-states are only quasi-bound because occasional third-party remote interactions may disrupt this stable, dynamic configuration. All of these situations can be more easily analyzed in the maximum-symmetric frame of reference, introduced earlier [173] known as the Symmetric Inertial Reference Frame (or **SIRF**). In this reference frame the total velocity (or momentum) of the two electrons is zero at any single time t as viewed from the (locally symmetric) origin of time (t = 0). In this local SIRF:

$$t'_n = -t_n \quad ; \quad \underline{x}'_n = -\underline{x}_n \quad \text{and} \quad \underline{v}'_{n-1} = -\underline{v}_{n-1}$$

The information function then simplifies to: $\Phi[q, \underline{x}_1; q', \underline{x}'_1] = \exp[\, i\,(4 + q + q')\, \underline{v}_{n-1} \bullet \underline{\kappa}_0\, \tau\,]\, (c\,\tau)^2 / r\, r'$

Like the candidate electrons, the target (emitting) electron will **only** select a partner electron if its partner is unique; this means there must only be **one** response received back at the decision time t'_1 otherwise no impulse is emitted at time t_n.

The target electron (#1) only becomes aware of its partner's location at its own 'answer-absorbing' time t'_1 when it is at position $\underline{x}'_1$ but it does not 'emit' its impulse $\Delta\underline{\mathbf{I}}_n$ until it reaches $[\underline{x}_n\,,\, t_n]$. In order to complete the interaction, this impulse must reach the candidate electron (#2) at its 'absorbing' location $[\underline{x}'_n\,,\, t'_n]$. This means that the impulse must be emitted in the direction of the interaction separation $\underline{S}_n$ where:

$$\underline{S}_n \equiv \underline{x}'_n - \underline{x}_n = \underline{r}_n = (\underline{x}'_2 - \underline{x}'_1) + (\underline{x}'_n - \underline{x}'_2) - (\underline{x}_n - \underline{x}'_1) = \underline{r}' + [(2 + q')\, \underline{v}'_{n-1} - (2 - q)\, \underline{v}_{n-1}]\, \tau = \underline{r}' - (4 - q + q')\, (\underline{v}_{n-1} / c)\, \Lambda_0$$

The luxon, Λ_0 [178] is about the size of a proton (about 10^{-13} cm) so that the deviation (i.e. $|\, \underline{S}_n - \underline{r}'\, |$) is always very small except for nuclear interactions, when $S_n \approx \Lambda_0$ and $v_n \approx c$ and even under these restricted conditions, the direction of $\underline{S}_n$ is exactly parallel to the direction of $\underline{r}'$ when the relative motions are co-linear (i.e. one dimensional). The temporal differences between the information delay (e.g. $t_n - t'_1$) and the momentum delay (e.g. $t'_1 - t_1$) involve the critical values of 3τ and τ which introduce the number 3 that has always been central to the triplet ideas of quarks and chromodynamics that are central to the **Standard Model** of elementary particles. These latter insights will be explored in a later paper when nuclear models involving only positive and negative electrons are developed.

In the case of remote EM interactions $S_n >> \Lambda_0$ so these small angular deviations are undetectable and for $v_n << c$ they are much smaller than the so-called 'spin' corrections that are of the order of one luxon, Λ_0.

Interaction Selection Probability

The statistical approximation model assumes that the probability that another electron will be selected for an interaction at its next chronon is inversely proportional to the spatial separation between them at the times of this next interaction, subject to the constraint that both electrons are on each other's light cone.

Optimization when the next impulse 'sent' at t_n to winning candidate and received at t'_n.

Radiation when $r >> c\,T$ ('far' approximation); non-SR when $v_n << c$.

Nuclear interactions when $r \approx c\,T$ and velocities are relativistic $v_n \approx c$; examined in a later paper on nucleons.

6.4 KEY ROLE OF THE SOURCE

It can be seen from its history that optics has focused on the 'path of the light' that has been assumed to travel from a distant source to the point of observation where the experimenters made their measurements. Almost no attention was paid to the activities at the source, with no theoretical models proposed until Niels Bohr's revolutionary model of the hydrogen atom. Even then, Bohr had to rely on a purely mathematical assumption to link the difference in the calculated energy levels to the observed spectral frequencies. This will not be the course followed here where the interaction becomes the focus and that means the **activity at the source** has to move onto center-stage. This will establish the physics behind the 'Bohr Rule'.

6.4.1 GENERIC SOURCE MECHANISM

It will prove useful to develop a generic model of optical sources that can be applied in all situations so that attention may then be refocused on other parts of the optical system. The near universal characteristic for a 'source' electron is that it undergoes periodic displacements across a small region of space. This requires the presence of one (or more) nearby 'driver' electrons that are interacting locally with the source electron to generate this local activity. In order for this activity to become an optical source, there must be a remote 'target' electron that must interact several times with the source electron over several local cycles. This scheme indicates that '**far**' radiation phenomena are examples of <u>three-electron</u> systems.

Before developing more detailed mechanical models of various sources of light, a more generic model will first be presented that includes the major features of all sources of EM radiation. The prototypical source will be modeled as a single electron that overwhelmingly moves under the influence of other (at least one) local source electrons (both positive and negative), referred to here as the 'driver' electron. In the case of EM source circuits, there must also be an external energy source to overcome localized energy losses ('resistance'). In many situations, the source and driver electrons form a stable, energy conserving system, where the source electron is moving at speed u_i with a kinetic energy is $\mathcal{K}_i = ½\, m\, u_i^2$. In the source system, these two electrons are interacting (on average) every $\mathbf{T_I}$ seconds. Since all action is always quantized, the kinetic action of the source electron $\mathcal{A}^K{}_i$ must be an integer multiple η_i of Planck's action constant h [164], where the index i labels this orbital; so:

$$\mathcal{A}^K{}_i = 2\, \mathcal{K}_i\, \mathbf{T_I} = \eta_i\, h \qquad \therefore \qquad \mathbf{T}_i = \eta_i\, h / 2\mathcal{K}_i \qquad \text{where} \quad \eta_i = 1, 2, \ldots$$

This orbital is characterized by a spatial distance $L_i = u_i\, \mathbf{T}_i = \eta_i\, h / m\, u_i$ that is the average distance traveled by this electron between 'driver' interactions. In all real situations, there are many multiple, stable orbitals in such source systems and the electron can continue to exist in any of them. In most cases, the orbital period $\mathbf{T}_i$ is a large multiple number of chronons, so that between each driver-interaction there is a finite probability that the source electron will suffer a small perturbation by interacting with a remote electron. That is a 'far' distance R away from the center of this source area; the definition of remote means that R >> L. This source electron, as a result of this remote interaction with the target electron must either leave this source area altogether and become a 'free' electron or it must move into another stable (final) orbital characterized by the integer parameter f (different from i, if non-degenerate). Even when the source electron is in a higher energy orbital it will continue in this new orbital until it is perturbed by another interaction – this is the actual physics hiding behind Einstein's assumption of <u>induced radiation transitions</u>. Typically, the energy levels in a local atomic system are too far apart for a direct transition to occur. In other words, the multi-electron atoms are quasi-stable and require a very small perturbation from a remote electron (of the order of $\varepsilon_0 = ½\, m\, b^2$) to **initiate** a transition but a <u>single</u> remote interaction will be too small to complete such a transition by itself. Thus, we must assume that the target electron participates in a series of **n** <u>consecutive</u> interactions with the source electron, which drops from the initial higher energy level i to the lower level f. All these 'far' interactions must occur almost in the same direction so that the <u>first</u> of these interactions must occur within any two interaction-events of the f^{th} orbital thereby reducing the source electron's speed in n increments of the speed quantum b (while increasing the target electron's speed), that is to say:

$$u'_f = u'_i - n\, b \qquad\qquad u_f = u_i + n\, b$$

Let the center of this source area define the origin of co-ordinate frame aligned parallel to the rectangular source area (that is, the x-axis is parallel to the length and z-axis to the depth). The simplest model is one where the source electron moves between any two of its local interactions parallel to the x-axis (z = 0) at a constant speed. Let the remote (target) electron be initially at rest at a distance R along the z-axis and near the planar origin (x ≈ 0 and y ≈ 0).

The individual local and remote interactions are illustrated in the next diagram and contrasted with the lowest order Feynman diagram. In these diagrams, the vertical scale is massively exaggerated as the target electron is very 'far'.

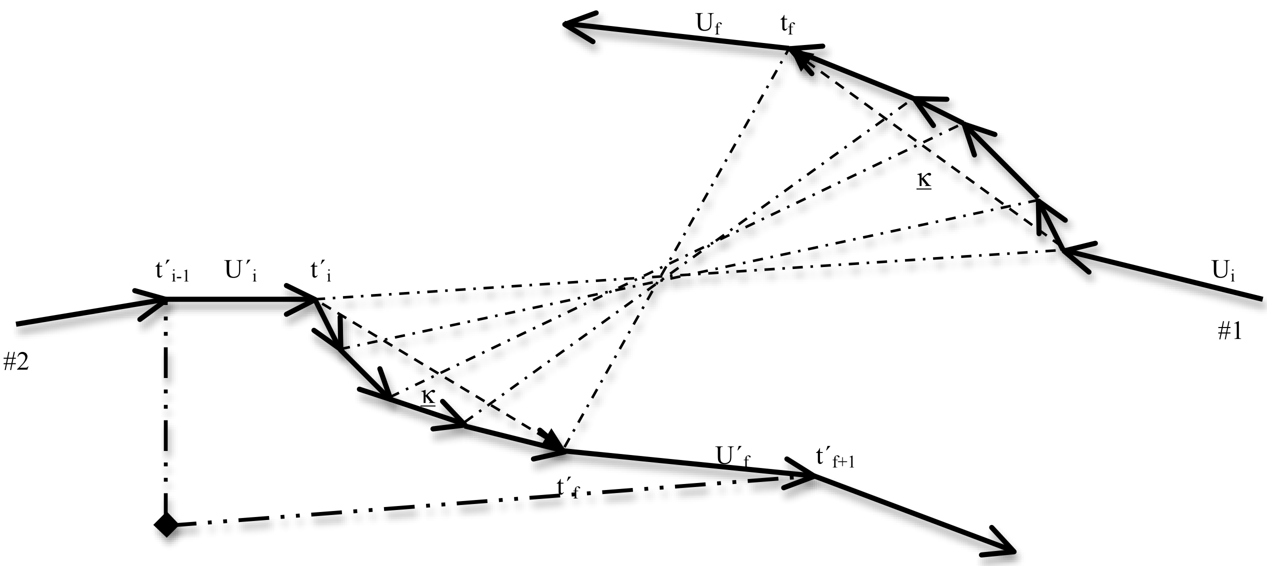


Fig. 10 UET radiation model

In this diagram, the source electron (#2) is interacting with its **driver** companion (#3) in a quasi-stable system; such as at time t'_{i-1} which leaves the source electron moving with speed u'_i until at time t'_i it chooses to interact with a remote electron (#1). These two electrons then continue to interact (n interactions). At time t'_f the source electron next chooses to interact again with its driver companion, emerges with speed u'_f. This leaves the target electron (#1) at time t_f to continue its own motion at speed u_f. If the vector sum of these micro-impulses in this exchange is denoted by $\underline{\kappa}$, then:

$$m\, \underline{u}'_f = m\, u'_i - \underline{\kappa} \qquad m\, u_f = m\, u_i + \underline{\kappa}$$

When this set of interactions are compressed to a single event at time $t'_i = t'_f$. then it resembles the QED lowest order (Feynman) diagram.

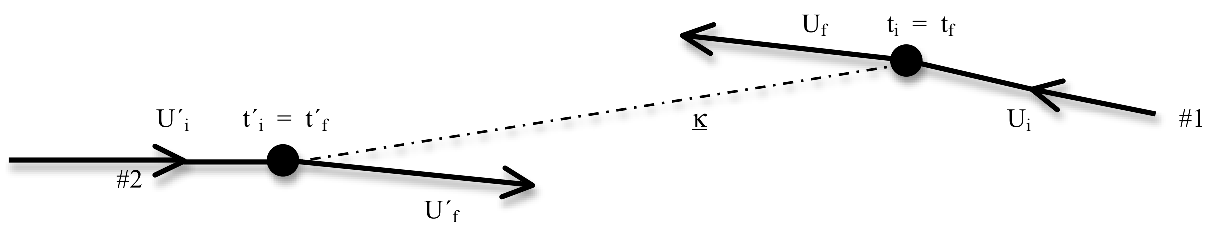


Fig. 11 QED radiation model

6.4.2 THE BOHR RULE

In Bohr's original, revolutionary paper that calculated the energy levels of the hydrogen atom [179], Bohr had to introduce an arbitrary relationship between the energy levels of two electron orbitals and the observed frequency υ of the light emitted when the electron moved from the initial ($\mathcal{K}_i$) orbital to the final orbital ($\mathcal{K}_f$); this is called the Bohr Rule:

$$h\, \upsilon = \mathcal{K}_i - \mathcal{K}_f$$

This section shows that this is a generic rule for all source transitions (both atomic and electrical). The focus here will be on the source alone so that the dashed notation may be omitted. The simplest case is the direct transition, where the source

electron has an initial kinetic energy $\mathcal{K}_i$ and at time t_i interacts with a remote (target) electron; at a later time t_f this source electron interacts once more with the remote electron and re-establishes its stable set of interactions with its own local 'driver' electron (as above).
The kinetic action in each orbital was seen above (§6.4.1) to satisfy: $\mathcal{A}^K_i = 2\,\mathcal{K}_i\,\mathbf{T_I} = \eta_i\,h$ so that the minimum change in this action is simply one quantum h. Thus, between these two orbitals the change in kinetic action is:

$$\Delta\mathcal{A}^K = \mathcal{A}^K_i - \mathcal{A}^K_f = h \quad \therefore\ 2\,(t_i - t_f)\,(\mathcal{K}_i - \mathcal{K}_f) = h \qquad \text{or}\quad \Delta t\ \Delta\mathcal{K} = h/2 \quad (\text{For convenience, } T_0 \equiv t_i - t_f)$$

The next step is to assume that this transition requires an intermediate interaction at a time t_1 when the source electron has a kinetic energy of $\mathcal{K}_1$. Let the first part of the energy difference be denoted by $\Delta\mathcal{K}_i$ and the second part by $\Delta\mathcal{K}_f$; these two differences divide the total difference in the ratio f to (1 – f). This 2-step process ends (at the source) at time $t'_f \neq t_f$.

$$\therefore\ \Delta\mathcal{K}_i \equiv \mathcal{K}_i - \mathcal{K}_1 = f\,(\mathcal{K}_i - \mathcal{K}_f) \quad \&\quad \Delta\mathcal{K}_f \equiv \mathcal{K}_1 - \mathcal{K}_f = (1-f)\,(\mathcal{K}_i - \mathcal{K}_f) \quad \text{Also: } \Delta t_i \equiv t_i - t_1 \quad \&\quad \Delta t'_f \equiv t_1 - t'_f$$

The quantization of kinetic action applies equally to both of these parts; thus:

$$\therefore\ h/2 = \Delta t_i\ \Delta\mathcal{K}_i = f\,\Delta t_i\ h/2\,T_0 \quad \therefore\ \Delta t_i = T_0/f \quad \therefore\ h/2 = \Delta t_1\ \Delta\mathcal{K}_1 = (1-f)\ \Delta t'_f\ h/2\,T_0 \quad \therefore\ \Delta t'_f = T_0/(1-f)$$

$$\therefore\ T'_0 \equiv \Delta t_i + \Delta t'_f = (t_i - t_1) + (t_1 - t'_f) = t_i - t'_f = T_0\,[1/f + 1/(1-f)] = T_0/f\,(1-f) \equiv \kappa\,T_0 \quad \therefore\ f^2 - f + 1/\kappa = 0$$

$$\therefore\ f = [1 \pm \sqrt{(1-4/\kappa)}]/2 \quad \therefore\ \kappa = 4 \quad \therefore\ f = 2 \quad \therefore\ T'_0 = 4\,T_0 \quad \therefore\ \Delta t_i = 2T_0 \quad \Delta t'_f = 2T_0$$

Therefore, the intermediate level is exactly halfway and each time-difference is exactly twice the original time separation.

This is a general result; if there are n – 1 intermediate interactions with the far electron then each of the n time differences Δt_j [j = 1, … , n – 1] are equally spaced; that is to say:

$$\Delta\mathcal{K}_j = (\mathcal{K}_i - \mathcal{K}_f)/n \qquad \therefore\ h/2 = \Delta t_j\ \Delta\mathcal{K}_j = \Delta t_j\ h/2\,nT_0 \quad \therefore\ \Delta t_j = n\,T_0 \quad \therefore\ T'_n = n^2\,T_0$$

When one **remote** (target) electron participates in a sequence of n interactions with the source then the target electron completes one complete oscillation or cycle in a time T_R seconds, where: $T_R \equiv 1/\upsilon = \Delta t_j$

Since each interaction is represented by complementary pairs of impulses that conserve momentum and kinetic energy across each completed interaction.

$$\therefore\ \upsilon = 1/\Delta t_j = 1/n\,T_0 = 2\,(\mathcal{K}_i - \mathcal{K}_f)/n\,h \quad \therefore\ h\,\upsilon = 2\,(\mathcal{K}_i - \mathcal{K}_f)/n$$

If we define υ_n as the frequency to complete n half-cycles; i.e. $\upsilon_n \equiv n\,\upsilon/2 \quad \therefore\ h\,\upsilon_n = \mathcal{K}_i - \mathcal{K}_f$

When an EM source repeatedly interacts with a remote electron, it must participate with its remote partner for many cycles, each involving the **same** time interval T_R seconds: this corresponds to monochromatic radiation of frequency υ. If we first consider the situation, where the source electron initiates its interaction into the future (a concept called here "**tirection**" – or temporal direction, otherwise known historically as '***spin***') then the digital model of the electron [177] indicates that each such interaction must be a multiple of the 'Send Forward' phase marker, $T_1 = 4N\tau$.

$$\therefore\ T_R = t_{j+1} - t_j = (j+1)\,T_1 - j\,T_1 = 4N\tau \qquad\qquad \therefore\ \upsilon = 1/\ 4N\tau$$

Here, N is a characteristic of the source situation and remains constant over macroscopically measurable timescales. Similarly, the receiving electron, in this scenario, must be receiving from the past over the same set of time intervals at multiples of the 'Receive Backward' phase marker, $T_4 = T_1 + 3\tau$. During each T_R cycle, the source electron must be able to continue interact with its remote partner every mth sub-cycle, so that: $t_j = T_0 + j\,T_R + m\,4N\tau$, so $t_{j+1} - t_j = T_R = 1/\,2\pi\omega$. This is the mechanism for Propagation of Frequency across space and time. This also explains why, when the receiving electron retransmits the interaction to a third electron, that it does so at the same frequency, υ. This is a **key feature** of optics but is rarely explained; it is just assumed 'as obvious'.

6.4.3 ATOMIC RADIATION

It is obvious that the generic model could apply directly to the Bohr model of the atom, where extra nuclear electrons are interacting primarily with the nucleus at the source. A similar model can be imagined occurring in the nucleus, especially if the positively charged protons are conceived as tightly bound collections of electrons and positrons. Both this atomic and this nuclear model will be developed extensively in subsequent papers in this series.

6.4.4 BLACKBODY RADIATION

Blackbody (or Planck) radiation occurs when solid bodies are subjected to significant local, external heat sources (§2.6.1). Planck mistakenly viewed this as 'cavity radiation' of the highly excited EM field. It is not – it is just the **interaction** of the electrons near the surface of the hot body (including the hot inner surface of the cavity) with remote 'cool' electrons (in the measuring device). The universal energy spectrum measured for ranges of frequency (known as the blackbody frequency spectrum) indicates that when local electrons are in thermodynamic equilibrium with their nearby excited local electrons and vibrating positive ions these surface electrons always absorb similar amounts of kinetic energy irrespective of the particular atomic arrangements of the surrounding source material. A fixed amount of this energy is then exchanged directly with the remote electrons before the exchange cycle can repeat. Planck was the first to create a mathematical model of this process (§4.1) by deliberately ignoring the 'hot' source electrons and abstracting out the remote interaction as energy transfers from a 'sea' of invisible oscillators – the favorite mathematical device for representing vibrations that vary over space and time. With only post facto justification, Planck introduced his mathematical hypothesis that the energy ε of each oscillator needed to be directly related to its 'natural' frequency υ, through the simple, linear relationship: $\varepsilon = h\,\upsilon$; or in its final form, an integer multiple n of this frequency: $\varepsilon_n = n\,h\,\upsilon$. The problems with this theory were summarized earlier (§4.5.1).

The simplest approach to deriving the Planck radiation law was proposed by Einstein in 1916 in his paper on the stimulated emission of radiation, reviewed earlier (§4.4) – this is described very elegantly by Pais [62], who emphasizes the central importance of induced emission in the final form (without this it would result in Wien's law). The key now is to reject the analogy made by Einstein that photons were **like** inert, gas molecules and realize that it is remote EM interactions that are the focus of all this activity. Of course, there may be many of these interactions occurring in any measurable time interval. Pais emphasizes that the (Bohr-like) frequency rule used here by Einstein: $\mathcal{K}_j - \mathcal{K}_k = \varepsilon_n = h\,\upsilon$ (where $n = j - k$) is seen as a necessary compatibility condition for a unique time duration $\Delta t_n = 1/2\upsilon$ that was introduced in the previous paper [164], where Δt_n is the duration of the transition period of the source electron in moving between the two energy states. This result indicates that the difference in energy levels of the source electron must equal the difference in energy levels of the remote (measuring) electron $\Delta\mathcal{K}$: this is no more than conservation of kinetic energy once the interaction is complete.

In 1900, Max Planck hypothesized that the minimum amount of (EM radiation) 'difference' exchanged between two linear harmonic oscillators (assumed to represent the EM field) was one quantum of action, represented by the symbol h. This minimum amount will be designated here by the symbol '$\mathbf{\Delta}_P$' (with the 'P' referring to Planck). As simple harmonic oscillators can be represented by two contra-rotating circular motions, this is equivalent to a single electron changing its action during one interaction by $\frac{1}{2}\,h_D$, where h_D is Dirac's (circular) version of Planck's constant ($h/2\pi$). This was the critical, foundational step in the development of quantum theory. This insight later evolved into Heisenberg's infamous indeterminacy principle, which in its minimal, temporal (discrete) formulation can be written as:

$$\mathbf{\Delta}_P\mathcal{K}_n\ \mathbf{\Delta}_P t_{n+1} = \tfrac{1}{2}\,h_D \qquad \text{If it is assumed that:} \quad \mathbf{\Delta}_P\mathcal{K}_n = \Delta\mathcal{K}_n \quad \text{then:} \quad \mathbf{\Delta}_P t_n = \Delta t_n / 2\pi$$

This would indicate that a single, Planckian EM unit of energy transfer (or single 'photon') transfers the equivalent of 137 micro-exchanges of kinetic energy ('photinos') in the digital electron model. The view seems plausible, as the energy-transfers must be the same, implying that the time differences should be detectable as differences in 'line-widths'.

Since action must always be quantized, the kinetic action $\Delta\mathcal{A}^K{}_n$ between these local interactions must be a multiple n of half of Planck's action constant h [164]; this is defined in terms of the source electron's kinetic energy $\mathcal{K}_n = \frac{1}{2}\,m\,u_n^2$. Thus, each set of n consecutive interactions, for each source electron involved must satisfy:

$$\Delta\mathcal{A}^K{}_n = 2\,\Delta\mathcal{K}_S\,T_S = n\,h/2 \qquad \therefore\ \upsilon = 1/T_R = 1/4T_S = \quad = \eta_n\,h/4\mathcal{K}_n \quad \text{where} \quad \eta_n = 1, 2, \ldots$$

Since energy is conserved across each **completed** single interaction it is conserved (eventually) across n such interactions.
So, in each phase: $\Delta\mathcal{K}_S = \mathcal{K}_j - \mathcal{K}_k \qquad \therefore\ \mathcal{K}_j - \mathcal{K}_k = h\,\upsilon$ Henceforth, referred to as **Bohr's Law**.

6.4.5 HERTZIAN RADIATION

In Feynman's model of QED the action of an EM antenna is treated as the independent emission of a very large number of photons so that there is no correlation between them (i.e. all have an equal probability of being emitted per unit time). The probability that an electron will absorb such photons is assumed only to be a function of the location of the electron at that time and is related to the classical vector and scalar EM potentials of the emission setup.

The nature of Hertzian radiation was discussed extensively in the third paper in this series [178]; this included a summary of Hertz's own explanation of his 1888 experiments in terms of Maxwellian electrodynamics, although Maxwellians were surprised at that time by these findings. Chapter 7 of that paper developed a mesoscopic model of conduction that replaced the epiphenomenon of "magnetic fields" in the space between conductors [179], with an inter-electron interaction within conductors. The inspiration there was Mead's view [180] of '**collective electrodynamics**', where: "*the behavior of **collective** electron systems is dominated by the interaction of each element with all the others*." This new model is based on local electronic repulsion in adjacent mesoscopic layers, so that battery-driven current only consists of the few extra electrons entering the conductor from the negative battery connection. These drift slowly, being pushed along by the next cohort of similar excess electrons. In contrast, in both the classical Drude or 'free electron gas' models, all the mobile electrons bounce around in all directions at high (Fermi) speeds making very many collisions with the ionic lattice.

The heart of this new mesoscopic theory of EM radiation is based on the universality of Joseph Henry's research [181] but here now interpreted in terms of current inertia, ultimately grounded on the electron's traditional inertia. Far radiation is seen here as the occasional remote interaction of a local, conduction electron that is experiencing local accelerations and decelerations in a closed 'source' circuit with an electron in the remote receiver. This mechanism, referred to as E**x**ternal **C**onduction **I**nteraction (**XCI**) [182], relied on the (anticipated) Saturation Hypothesis acting on some of the source electrons. This approach showed that changes in the physical momentum of the conduction electrons, originally generated by fluctuations in the source circuit at frequency υ, could result in energy transfers $\Delta\varepsilon$ to the remote electrons, satisfying the Bohr frequency rule: $\mathcal{K}_i - \mathcal{K}_f = \Delta\varepsilon = h\,\upsilon$, where $\mathcal{K}_i$ and $\mathcal{K}_f$ are two of the possible kinetic energy levels of the source.

The actual Hertzian experiments was recovered in terms of Linear Far Interaction models when high frequency current oscillations in open conducting arrangements of straight and circular antennae induced currents in a single set of remote charges [183] (the 'target'). Nowhere in this analysis was any use made of the concept of "waves in the æther" that connected receivers to transmitters. This demonstrated that realistic, physical models could be created that **explained** physical effects, not just the 'discovery' of mathematical equations (summaries) that predicted these results.

6.4.6 COULOMB FORCES

Once again, this paper will disregard the so-called Coulomb Law of electrostatic forces; it was dismissed earlier [184] on the grounds that this hypothesis (first proposed by Joseph Priestley) and claimed to have been given experimental confirmation by Coulomb has **not** been reproducible [185] in recent experiments (a **hugely important result** that seems widely to hve been ignored). Furthermore, this was a macroscopic scale 'experiment' and this 'law' of electrostatic force has **never** been empirically confirmed at the level of the electron, which is never at rest throughout any interaction. This research has also shown that continuous, non-instantaneous 'forces' are incompatible [149] with real microscopic particles that exhibit inertial mass, such as the electron. Accordingly, this research focuses on Newton's original idea of **impulse** for instantaneous changes in inertial particle's momentum.

Further, the vector law of the **addition of forces** has only been observed at the macroscopic level and **never** over very short time durations. In both cases, a statistical viewpoint is the best that can be claimed. The popular Coulomb gauge in CEM is not static (i.e. $\underline{H} = 0$, $\underline{E}$ = constant) but is an **averaging** approximation over the timescale associated with the frequency measurements and where the velocity effects (i.e. magnetic field) net to zero over this scale.

7. LIGHT AS REMOTE ELECTRON INTERACTIONS

Section VII returns to the experimental phenomena that were introduced in sections II & III and were explained by classical optical theories in section IV. Here these experiments are re-interpreted in terms of the theory developed in section VI. This section is **vita**l to this paper, readers will have to judge for themselves whether these new explanations appear sound or not.

7.1 THE 'NATURE' OF LIGHT

7.1.1 LIGHT IS NOT A WAVE OR A PARTICLE

Contrary to an almost universal impression, neither light rays nor light waves have actually ever been observed in optical experiments. These have arisen from only the mathematical techniques introduced to describe the phenomena. As happens too often in theoretical physics, the mathematics has been reified, when the symbols have been assumed to correspond, one-to-one with real existents. Key symbols have ended up in equations that imply these 'symbols' move across space in time.

The present theory agrees completely with the leading operationalist, P.W. Bridgman when he declared [186]: "*There is no physical phenomenon whatever by which light may be detected apart from the behavior of source and absorber. ... Hence from the point of view of operations it is meaningless to ascribe any physical reality to light in the intermediate space, so the idea that light, as a **thing** traveling, must be recognized to be pure invention*."

Sine waves are the simplest complete set of mathematical functions, which can be used to represent **any** spatial variation in one-dimensional space. Spherical harmonic functions are the equivalent complete set of mathematical functions that can represent any spatial variation in three-dimensional space. It is not a coincidence that these two sets of functions appear as waves when representing variations in space of all physical phenomena over time. However, it must be pointed out here that particles can appear to be the source of temporal fluctuations, if they present an oscillating property to the world; when they move. Such **pulsating-particles** would then appear to present wave-like characteristics: this is the solution of the QM paradox.

7.1.2 LIGHT BASED ON ELECTRON INTERACTIONS

All earlier models of light, when they consider its physical basis, have conceptualized the interaction as an **object** (wave or particle) that is **created** from a separate kind of objects (the 'emitters'). This decision reflects that both words are nouns (although with vastly different metaphysical implications) and the ancient philosophical approach [187] to construct the world from fundamental substances ("fire, water, etc."). As an object, light must then exist as an independent entity moving away from the emitters carrying with it energy and momentum until it collides with another set of objects (the 'absorbers') when it ceases to exist. In contrast, UET rejects this approach and proposes that reality is **only** constructed from electrons that alter each others motion via a single interaction between a pair of electrons separated in space without introducing any additional, intermediate 'carrier'. This is explicitly in the Newtonian tradition of action-at-a-distance (or Direct Action) but, unlike Newtonian gravity, there is here an explicit difference in time between the time of emission and the time of absorption; i.e. this is an asynchronous model (ADA). Although this conceptual model is analyzed in terms of two mathematical impulses representing the emission and absorption, this is merely a computational device and is **not** meant to represent two separate and distinct real processes but should be viewed as the inseparable "two sides of the same coin".

Wheeler and Feynman's action-at-a-distance theory [97] appears similar to UET but makes the following assumptions: 1) the acceleration of an electrified point-charge is the source **of** the EM fields, whereas UET views an electron's acceleration (discrete change in velocity) **only** as the result of when the electron interacts with another electron. 2) EM fields acting **on** a point-charge arise only from other electrons, whereas UET totally **rejects** the field concept. 3) W-F EM fields are represented **by** one half of the retarded plus one half of the advanced Lienard-Wiechart solutions of the Maxwell Equations from a point source. 4) sufficiently many particles are present at remote distances to absorb completely the radiation given off by the accelerated point-charge. In contrast to#3, UET views the remote interaction as alternating between retarded and advanced direct interactions between point-like electrons; whereas in contrast to #4, UET retains only the saturated interaction between **pairs** of electrons.

The **photon** concept is an implicit recognition of the quantized physical nature of the interaction between two electrons. The particle's temporally oscillating property is the recognition that the electron's awareness of other electrons is periodic in time, especially when it is moving across space – this is elaborated for the digital electron in the next paper.

7.1.3 LIGHT AS OSCILLATING INTERACTIONS

EM Frequencies

There are only two ways to generate electrical oscillations of a given frequency in the present theory: either the synchronized, cyclic movement of large collections of electrons between two locations (e.g. antennas, klystron, etc.) or by moving a single electron between given orbitals in isolated atomic-scale systems. Mechanical acceleration is not allowed.

The Frequency Model

The frequency model used herein and henceforth was developed previously in sections 6.4.1 and 6.4.2 (the 'Bohr Rule'). The idea of wavelength arises from altering the spatial separation between the source and the target; only when this distance becomes a multiple of the temporal periodicity does an interaction occur: this resulting spatial periodicity is called the wave-length for the temporal oscillations of the frequency. In other words, the EM interaction is always about time, while space plays only a subsidiary role. The wavelength emphasis reflects the human mind's facility with static imaging over process.

7.2 THE 'PATH' OF LIGHT

Even though the present theory rejects the idea that 'light' is an entity that travels through space, it is still possible to talk about the 'path of light'; but now this is a **logical** concept constructed from the sequence of locations where a single interaction activates a series of electrons as these electrons pass along the energy and momentum 'disturbance'.

7.2.1 THE OPTICAL PATH

In the present theory, the idea of an optical path is only an aide to the imagination. In reality, it is seen as a sequence of electrons (across space), which participate serially in each interaction, originating at the source set of electrons and 'hop-scotching' pairwise across space over time. It is vital to emphasize that there are **no** carriers of momentum in this theory.

7.2.2 ACTION AT A DISTANCE

Interactions as Rays

In the UET model, since light is not viewed as an entity, it can only interpret rays as a mathematical representation of the direct, **geometric lines** linking electron-electron interactions along the optical path and, like rays, the finite number of interactions, from source to final absorber, can be counted over any finite time.

Remote electrons interact either directly (along their complete line-of-sight, relative centers) or indirectly, via one or more intermediate electrons that are 'temporally near' the direct 'ray'.

```
                                                    o                          o-------o
a)   o------------------------------o      b)  o ------   ----------o     c)  o ---       ----o
```

In the UET model, there are no traveling objects to collide with one another, which was Huygens principal objection to a 'particulate' model. In other words, any action-at-a-distance model is explicitly **not** a 'moving particulate' model, nor is it a 'traveling wave' model. Also, unlike Huygens, there are no new spherical wave-fronts originating along the way.

Great distances

One of the initial insights leading to the development of UET was the realization that we can see very distant light sources like the 'fixed' stars – the **fact** of the energy transfer has to be independent of the distance between the source electrons (in the star) and the target electrons (in the eyes). It is the strict requirements of the electron selection conditions (including the requirement that the temporal separation be an exact number of luxons) that allow humans to see the stars at night. The 'far' energy and momentum unit transfers in the UET model are independent of the relative separation or relative velocities of the two interacting electrons but the rate of exchange will vary as these are determined by the number of possible interactions per second between each interaction, which is not constant. We see stars, because the stellar electron has **no** closer partner electron to interact with than with one of the electrons in our eye, which is available just at 'the right time, at the right place'.

Alternate Optimization Possibilities

There are several possibilities for defining the fundamental Optimization Rule for identifying which electrons will pair together into a single interaction:

1) smallest spatial separation 2) smallest temporal separation 3) minimum change in total action.

The Optimization Rule (Global Least Action)

The discovery that Planck's constant *h* is a universal measure of smallest action strongly suggests that Nature's optimization is based on **Least Action**. This is reinforced by the fact that Newton's Laws of Motion for Classical Mechanics [188] may also be reformulated as a Least Action principle. This research programme was also inspired by the researches of William Rowan Hamilton (the Irish genius who invented quaternions [189]). His own first research was focused on the ray paths of light that led to the invention of his "characteristic" function that summarized the paths of light through any optical system based on Fermat's principle of Least Time, whether light was viewed as waves or particles. This later led to the extension of his characteristic function from geometric optics to particle mechanics that invoked Maupertuis's Principle of Least Action; this directly inspired Schrödinger when he was developing his now famous "wave mechanics". This programme also views inter**action** as fundamental and this involves an exchange of **action** [190]. As mentioned earlier herein (§4.1), even Planck was ready to forgo the universal validity of the Hamiltonian differential equations if he could retain the Principle of Least Action. Therefore, this will be the choice made in the present theory for interactions at the micro-level of electrons. Thus, at each 'tick' of the Cosmic Clock, each electron selects a partner electron that generates the least action in the next cycle, subject to the global constraint that all these selections result in a **global minimum in the total action**.

Fermat's Principle as the Local Optimization Rule

Fermat's (optical) Principle of **Least Time** is reflected in the UET selection possibility #3 (above) that the preference of any electron is to interact with its closer neighbors rather than its more distant ones, as long as this electron is 'available'. This is a suitable compromise when only local conditions are dominant (a notorious approximation in theoretical physics). The generalized principle of Least Time in its modern form was stated by Fermat in a letter dated January 1, 1662, to Cureau de la Chambre. It was met with objections made in May in the same year by Claude Clerselier, an expert in optics and also a leading spokesman for the (Catholic) **Cartesians** at that time. Amongst his objections, Clerselier states:
... Fermat's principle cannot be the cause, for otherwise we would be attributing knowledge to nature: and here, by nature, we understand only that order and lawfulness in the world, such as it is, which acts without foreknowledge, without choice, but by a necessary determination. Once again, we see the spokesmen of religious reaction try to maintain their unique human characteristics.

This has been the standard 'Man as Pinnacle' assumption that has stood since Ancient Times. The present theory challenges this assumption with the Selection Mechanism attributed to all electrons to implement the saturation hypothesis (§6.3.5).

Fermat's principle is the main principle of quantum electrodynamics [191], where it states that any particle (e.g. a photon or an electron) propagates over all available (unobstructed) paths and the interference (sum, or superposition) of its wave-function over all those paths (at the point of observer or detector) gives the correct probability of detection of this particle (at this point). Thus, the extremal (shortest, longest or stationary) paths contribute into this interference most, as they cannot be completely canceled out. It agrees with the Huygens-Fresnel principle in the small wavelength (Far-Field) limit.

In the present theory, electron selection goes to the nearest electron that satisfies all the above selection conditions as this minimizes the action exchanges involved. If the optimal target electron is accompanied by a pair of other electrons equally spaced further apart on both sides then the 'central' electron will be closest to the source. In effect, this is remote action in a straight line in minimum time across empty space. These principles are sufficient to derive the laws of reflection and refraction, as is well known.

Fresnel's Construction

The Huygens' (or Fresnel's) Construction is **not** viewed here as valid in a vacuum but it is a reasonable approximation in a real medium with atoms present to scatter incident excitations; it is a 'good enough' statistical model for multiple interactions between electrons in different atoms when interacting at 'low' frequencies within a material medium. Secondary waves involve an '**obliquity**' factor $(1 + \cos \theta)/2$ that leads primarily to forward secondary transmissions. Fresnel had to introduce an arbitrary quarter-wave phase advancement in his secondary waves to create this needed factor.

7.2.3 INTERACTIONS ACROSS MATTER

Light travels in a straight Line through Matter

The model for the transmission of 'light' through a uniform medium is similar to the scheme presented by Feynman [192] in his masterpiece *QED*. There he had his 'little arrows' (one for each intermediate path segment) whose length represented the square root of the probability of an event with the arrow's 2D direction reflecting the fraction of a cycle completed over this unit of time. These arrows represented Feynman's model of photons travelling across space in straight lines from one point **of** space to another, spanning a small time difference t_j for each segment, denoted by an identifier j. He admits that he is **not** offering a deeper description of "*how it actually happens*". In the present theory, each segment represents the possible interaction between one electron **at** one point **in** space with another, remote electron **at** another point **in** space. The arrows are vector-summed to reflect the total, combined probability so that the square of the total vector is proportional to the combined probability. In effect, Feynman was just presenting a <u>visualization of the complex Fourier decomposition</u> of any curve in space. Each fractional probability amplitude $\mathcal{A}_j$ was one of the Fourier coefficients, with the light frequency being represented by the angular velocity ω :

$$\mathcal{A}_j = A_j \exp[i\,\omega\, t_j] = A_j\,[\cos[\omega\, t_j] + i\sin[\omega\, t_j]] \text{ with probability of event j being: } \mathcal{P}_j = \mathcal{A}_j{}^*\,\mathcal{A}_j$$

In contrast to Feynman's picture of light going to <u>every</u> point in space, the present theory only permits interactions at points in space <u>occupied</u> by an electron that is 'free' to participate in an interaction at that instant of time; this defines a set of locations $[\underline{x}_j\,;\,t_j]$ or line segments L_j between $\underline{x}_j$ and $\underline{x}_{j+1}$. Let V_j be the 'speed of light' in the medium spanning segment L_j and n_j be its refractive index. Let the total path from point $(\underline{x}_1\,;\,t_1)$ to point $(\underline{x}_n\,;\,t_n)$ going through κ segments be called $\mathcal{L}_\kappa$.

$$\therefore\ V_j = \Delta\underline{x}_j / \Delta t_j = (\underline{x}_{j+1} - \underline{x}_j) / (t_{j+1} - t_j) = c / n_j \qquad \therefore\ \mathcal{L}_\kappa = \textstyle\sum_j L_j \quad \text{with} \quad L_j \approx \Delta\underline{x}_j \quad \therefore\ \mathcal{T}'_\kappa = \textstyle\sum_j \Delta t_j = t_n - t_1$$

$$\therefore\ \mathcal{T}'_\kappa = \textstyle\sum_j \Delta t_j = \sum_j n_j\,\Delta\underline{x}_j / c \quad \therefore\ L_j = n_j\,\Delta\underline{x}_j / c \quad \therefore\ \mathcal{L}_\kappa = c\,\mathcal{T}'_\kappa$$

We now assume that there is a probability G_j for an interaction to progress between electrons at $(\underline{x}_j\,;\,t_j)$ and point $(\underline{x}_{j+1}\,;\,t_{j+1})$. This requires that at time, t_j the electron must be 'uncommitted' and in the 'Send' state $\mathcal{S}_j$ while the next electron is in its 'Rcv' state $\mathcal{R}_{j+1}$ at time $t_{j+1;}$ (see §6.3.3). This can be written: $G_j = \mathcal{S}_j\,\mathcal{R}_{j+1}$ as both probabilities must comply. However, the present theory views time as progressing symmetrically, at the interaction level, so the complementary situation is also valid. This may be written as: $G_j^\dagger = \mathcal{S}_{j+1}\,\mathcal{R}_j$. Thus, the probability that the j^{th} segment of the 'light path' is "activated" becomes $\mathcal{P}_j$. Since the two electron states (Snd and Rcv) are alternative (exclusive) possibilities we introduce the complex variable $\mathcal{A}_j$, defined as: $\mathcal{A}_j = \mathcal{S}_j + i\,\mathcal{R}_j$, with $i^2 = -1$. Noting that if $\mathcal{S}_j = 1$ [or 0] then $\mathcal{S}_{j+1} = 0$ [or 1]; similarly for $\mathcal{R}_j$ and $\mathcal{R}_{j+1}$, so that always: $\mathcal{S}_j\,\mathcal{S}_{j+1} = \mathcal{R}_j\mathcal{R}_{j+1} = 0$

$$\therefore\ \mathcal{A}_j\,\mathcal{A}_{j+1} = (\mathcal{S}_j + i\,\mathcal{R}_j)(\mathcal{S}_{j+1} + i\,\mathcal{R}_{j+1}) = (\mathcal{S}_j\,\mathcal{S}_{j+1} - \mathcal{R}_j\mathcal{R}_{j+1}) + i\,(\mathcal{S}_j\,\mathcal{R}_{j+1} + \mathcal{R}_j\,\mathcal{S}_{j+1}) = i\,(G_j + G_j^\dagger) = i\,\mathcal{P}_j$$

$$\therefore\ \mathcal{P}_j = -i\,\mathcal{A}_j\,\mathcal{A}_{j+1} \qquad [\,\mathcal{P} = \textstyle\sum_j \mathcal{P}_j = -i \sum_j \mathcal{A}_j\,\mathcal{A}_{j+1}\,]$$

This suggests a new meaning for the self-product of $\mathcal{A}_j$ that will be designated by the symbol $P_j = \mathcal{A}_j\,\mathcal{A}_j$

In contrast to Feynman's model where the 'time' parameter may take on any value, here they are constrained to a finite multiple N_j of the chronon, τ, so that Feynman's cosine and sine factors only take on the binary values zero and one. In most cases, Feynman assumes that the probability amplitudes $\mathcal{A}_j$ are the same [193], here they are always zero or one. It must be said that Feynman does not justify using complex amplitudes – he just assumes that this is the most general form.

In the present theory, each electron cycles around its two interaction states over time, so that in a complete cycle both are equally likely to be in each particular state. In this theory, it is the 'Information Wave' that is selecting pairs of electrons that are optimal for participating in each interaction j (see §6.3.3). In a previous paper [194], the 'snd' and 'rcv' states were found to correspond to the QM 'spin' states, $|\uparrow\rangle$ and $|\downarrow\rangle$ that can be given simple, binary matrix representations.

In order for an electron to interact at time, t_j it <u>must exist</u> at the location xj at that time <u>and</u> it must be ready to <u>interact</u> at that same time. Let the first potentiality be represented by the probability $P_E[t_j]$ and the second by $P_I[t_j]$. For the j^{th} interaction to occur then both electrons <u>must</u> exist at their locations at their respective times; i.e. $P_E[t_j] = 1$ and $P_E[t_{j+1}] = 1$.

$$\therefore\ \mathcal{A}_j = P_E[t_j]\, P_I[t_j] = P_I[t_j] = (\mathcal{S}_j + i\,\mathcal{R}_j) = |\uparrow> + \ i\,|\downarrow> = [1,0] + i\,[0,1]$$

$$\therefore\ \mathcal{A}_j^\dagger\, \mathcal{A}_j = (\mathcal{S}_j + i\,\mathcal{R}_j)^*\,(\mathcal{S}_j + i\,\mathcal{R}_j) = (\mathcal{S}_j - i\,\mathcal{R}_j)\,(\mathcal{S}_j + i\,\mathcal{R}_j) = (\mathcal{S}_j)^2 + (\mathcal{R}_j)^2 = <\uparrow|\uparrow> + <\downarrow|\downarrow> = 2$$

Thus, $\mathcal{A}_j$ may be identified with the conventional wave-function $\psi[\underline{x}, t, \lambda]$ of the electron, with spin λ at location $\underline{x}$ at time t in quantum mechanics. The electron '**spin**' actually defines the temporal direction (or '**tirection**') that an interaction may occur [174]. The factor 2 reflects the 'polarization' of light, again now interpreted as a temporal interaction direction, rather than a rotating vector in space (the SU2 group is isomorphic with the SO3 group – 3D spatial rotations). Finally, the factor i in the above segment probability factor, $\mathcal{P}_j$ reflects the quarter-wave 'fudge' factor that Fresnel had to add to Huygens' principle. It corresponds to the fact that the temporal difference at both ends of the interaction segment must differ by one chronon (in the basic 4 chronon cycle) as can be seen [195] from the form the Time Evolution operator, $\mathcal{T}[\Delta t_j]$:

$$\mathcal{T}[\Delta t_j] = \exp[i\, 2\,\pi\, \Delta t_j /4\tau] = \exp[i\, \pi/ 2] = i \quad \text{whenever } \Delta t_j = (4\, N_j + 1)\, \tau \quad \text{for all integer } N_j \quad \text{then} \quad \mathcal{A}_{j+1} = \mathcal{T}[\Delta t_j]\, \mathcal{A}_j$$

In comparing the present theory with QED it can be seen that QED is a 'positive' theory that assumes <u>all</u> the paths exist, each 'occupied' by a real photon but now here it is a 'negative' theory where the absence of a balancing alternative has an effect on which pathway from the source to the final target is chosen. Only <u>one</u> path is now chosen and only <u>one</u> interaction occurs at the final target. Both are 'holistic' theories, in the sense that **all** possibilities determine what actually happens. Even altering the situation by one electron (addition or removal) can change the actual situation. In this sense, both theories are about '*potentia*' or probability in the modern viewpoint. In summary, Feynman's theory of light is about hypothetical <u>*photons*</u> moving **everywhere** through space at **all** times while this theory is about hypothetical <u>interactions</u> occurring and propagating only between **some** real electrons at finite times.

7.2.4 ATOMIC SCATTERING

The EB article on light [196] reminds the reader that: "*When light is scattered off a single atom the effects are too small to be observed. Atoms most usually react by emitting waves of the same frequency and in a definite phase relationship to the incident light*." Since the wavelength of light is much larger than the size of atoms, it is a reasonable approximation to view all of the atom being exposed to a uniform 'force field' from the light beam so that optical scattering is independent of the direction of the incident light but still dependent on its frequency and polarization. All refraction effects in wave theories of light are seen as being due to combining the influences from the direct and secondary interactions. Real scattering involves many electrons in myriads of atoms re-interacting with electrons in other atoms in a vast, many-body complex. Each one of these secondary interactions is exquisitely synchronized across space and time as all interactions must remain on each electron-pair's 'light-cone'. In the present theory, <u>interference</u> is seen as **prior** to the act of interaction when possibilities are rejected (see §6.3), they are not seen here as the positive effects of combining multiple 'wavelets'.

Coherent Systems

Coherent systems optimize their total activity by synchronizing their pair-wise selections globally; random systems optimize their activity at best on a local level, well below the global, which is then calculated using phase-incoherent relative timings. This is the explanation for optical transparency in crystals, where the re-transmissions are synchronized between atoms across macroscopic distances, while opaque materials cannot achieve this degree of coherence, resulting in the random scattering (or interactions) of the multiple retransmissions.

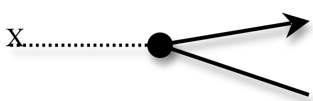
Transparency & Translucency

Transparent objects allow light to pass through them while preserving the sharpness of the originating source. Translucent materials allow some light to pass through but the sharpness of the optical images is soon lost. Opaque objects partially allow transmission but all clarity is destroyed. At the atomic level in all opaque media, the constituent atoms scatter the incoming light in an incoherent (multi-directional) manner, so that the cohesion of the original image is soon lost. In the new theory, incoherent propagation implies that many different (sideways) optical paths are optimum across the medium.

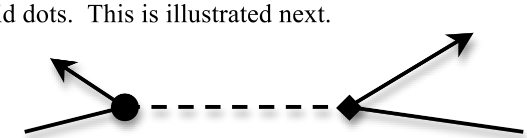
7.3 REFLECTION & REFRACTION

7.3.1 FEYNMAN'S MODEL OF LIGHT

Feynman's approach to Quantum Electrodynamics (QED) was introduced in section 5.2.2 and re-interpreted in section 5.3.4. Since the present theory is based on that theory, it will be the basis for the present exposition. The clearest view of this theory was given by Feynman himself in his Mautner Lectures [68] at UCLA in 1982 and presented in written form in his gem: *QED*. Beginning with his Introduction, Feynman emphasized two key elements: 1) **nobody** (including himself) understands what this theory means [197] 2) light behaves like a particle [198], not a wave; indeed, "*light is made of particles*". He convincingly makes the second point by describing the discrete response of photomultipliers to very dim light. However, in all his examples, Feynman talks about a photon interacting with electrons but he ignores the activity of the light source, always talking about an existing photon. The present theory always begins with the electrons in the source and follows the interactions between electrons. In other words, the emphasis here is switched from the photon acting at a 'field point', often occupied by an electron, to the asynchronous interaction between two electrons. The key difference is that in this theory there is **no** 'carrier' moving across space conveying momentum but only action-at-a-distance: the revolutionary concept introduced first by Newton in his theory of universal gravitation. Like Newton, we will 'not make a hypothesis' to explain this phenomenon but simply propose that this is an inherent property of all electrons. If the reader cannot accept this possibility, then like Newton's critics, such as Leibniz, they should proceed no further. This implies one major difference with Feynman's model; here there is **only activity where there is a real electron**, Feynman (following Maxwell and all the other believers in field theory) still focuses on every point in space, whether empty of matter or not. This means that many of the diagrams that Feynman is famous for, can be retained in the present theory but now only electrons are real and only locations of real electrons are valid. The concept of a photon is replaced by an interaction (represented by a straight dashed line) connecting the two electrons (represented by straight solid lines) that must always be on each other's light cone; imaginatively, this means that 'light' is viewed as always "travelling at light speed, *c*". In contrast, Feynman's photon can literally move across space at all speeds, even at super-luminary [199] speeds. The two ends of each interaction (at different times) are here represented by solid dots. This is illustrated next.



1) Feynman's model



2) Universal Electron Theory

7.3.2 PARTIAL REFLECTION AT BOUNDARIES

Much of the exposition in Feynman's *QED* is centered on transmission of light through a parallel slab of glass [200]. He makes the key point that light is really not affected by surfaces (they are a convenience for us), stating that: "*An incoming photon is scattered by the electrons in the atoms in the glass and a new photon may come back up to a detector*." (on the same side as the source). He focuses on the **time** perspective, using an imaginary stopwatch that travels with the photon. His theory associates a constant 'ticking rate' with each monochromatic photon (represented by a rotating arrow, like the hand of a fast stopwatch; the rotation rate corresponding to the frequency of the optical light source). Once a photon has been emitted, there is no further turning of this arrow as a photon goes from one point to another in space-time. Feynman begins by tracking a series of consecutive photons from a monochromatic source hitting a set of electrons along a central column below the reflection point on the slab's surface, where a new photon is emitted back to the detector. The electrons are at different depths below the surface so that the total travel times of each photon will arrive at exactly the same time at the detector if the depths are chosen appropriately. The only variations in the possible photons are the time of initial 'emission' and the time of 're-transmission'. The key point here is that any of these possibilities could be the one that occurs at a given moment of reality (as judged by the detecting photomultiplier) but, even more importantly, only one photon is detected at any time. Feynman finally shows that adding all of these penetrating possibilities is equivalent to just adding the results of a single scattering from the top and bottom atoms in the slab – a **simplification** he then uses everywhere else and one that can also be used here.

Experiments on different materials can count the number of photons that get reflected back upwards in the direction of the source. In many glasses, using monochromatic red light sources, this is shown to be only about 4% for very thin slabs. By varying the thickness of the slab (effectively adding multiple thin slabs together), the percentage can vary from zero to 16%. The current theory reinterprets this as 4% for interacting backwards per retransmission and 96% for interacting forwards.

Semi-Silvered Mirrors

A semi-silvered mirror transmits 50% and reflects 50% of the incident light. Neither Newton nor Feynman could offer any explanation or mechanism for the fact that some light is reflected at a surface and some penetrates. In this theory, this phenomenon is viewed as the (exclusive) selection by the oscillating electron in the mirror either with an electron in the mirror's material or with another electron back in the incident medium (often in the detector). It is only the presence of the detecting electron above the surface that provides this choice for the electrons in the mirror or crystalline slab. It is therefore a **prediction** of the present theory that distancing the source and removing all electrons above the crystalline slab will increase the transmission through the transparent slab.

In the QED model, the single photon traversing the semi-silvered mirror undergoes a seemingly probabilistic choice as it ***decides*** to reflect or refract from the mirror's surface. In UET, the last electron in the mirror, excited by the chain of interactions, makes a deterministic choice (before it leaves the mirror) with an electron in the direction of the interaction ('forward ray') or with an electron back in the mirror material (or possibly on the reflecting side of the mirror). As humans, we are ignorant of the specifics in <u>every</u> instance, so that <u>we</u> approximate this choice with a statistical calculational method. This model provides a mechanism for Newton's fluxions except there is no carrier 'light particle' as he imagined; the choice is being made prior to the interactions occurring between the electrons involved along the actual path finally selected. When a backwards reflection occurs then the 'reversing' electron must 'absorb' the appropriate EM momentum and this is spread around the atoms in the mirror, causing the mirror to exhibit detectable motion.

Mirror Reflection

In describing the action of a mirror (reflecting incident light back at the same angle as it makes hitting the mirror), Feynman sets up a symmetrical model. Here the monochromatic source is emitting one photon, at a time towards the mirror, and a (directly shielded) photomultiplier detector is located at the same angle and on the same side (above the mirror). Feynman points out that there are millions of possible paths for photons to hit the mirror before "bouncing back" to the detector. He simplifies his calculation by dividing the finite mirror into a finite number of smaller pieces. He calculates the probability of a photon hitting each segment and bouncing into the detector by assuming that all initial photons have the same probability of first hitting any segment. Again, he emphasizes the timing differences between each of these pathways with the central segment contributing the shortest 'travel' time, while symmetrically placed segments on each side take the same (but longer) times. Feynman ends up with a visual demonstration of Fermat's Principle of **Least Time**, illustrating Snell's Law. The same principle applies in the present theory: electrons in the central segment of the mirror will be the ones most likely to be <u>selected</u> by the emitting electrons in the source; these will then (sometimes) reflect back to the nearest detector electrons.

Reflection Grating

Feynman introduced his model of the mirror to show that segments away from the center of the mirror also play a key role. He eliminates alternate segments where his 'photon arrows' all point in the same direction, leaving only segments giving these arrows that point in the opposite direction. He emphasizes that the locations of the eliminated segments vitally depend on the frequency of the light source. This is the key to understanding this grating effect. Yes, all the remaining segments offer an opportunity for their electrons to occasionally be selected but it is because now they are not <u>de-selected</u> by the other segment's electrons on the opposite side of the centre line. This illustrates the key selection rule developed earlier (§6.3.3).

7.3.3 REFRACTION

As Newton and Feynman both recognized, the phenomenon of refraction is the complement of reflection. When light is viewed as part of a discrete process then whatever fails to be reflected (backwards) must be go forwards. In the case of activity at a boundary between two media (one of which may be air, which as a gas behaves optically almost like a vacuum), there is also the observed bending of light to the normal in the medium of higher refractive index. Feynman's explanation follows closely his mirror model but now the mirror is replaced with a bath of water with the detector submerged below the surface. Feynman uses the analog of a lifeguard running along the beach to save a person out in the water. The trick is to decide how to balance the faster running time against the slower swimming time, with the solution being the point of leaving the beach and entering the water. Again, it is the path of shortest time (Fermat) that is selected, remembering that light 'travels' faster in air than in water (see next). This is also the explanation in the present theory but physically it is because of the greater 'delay' times in a denser medium with the optimum global solution picking the critical retransmission electron.

7.3.4 THE 'SPEED' OF LIGHT IN DISCRETE MEDIA

Light Speed as a Metric

The value of the universal constant c (3×10^{10} cm/sec) is **not** viewed, in this theory, as the 'speed of light' or the limiting speed of material objects but the **metric** linking the spatial separation of electrons (Δx) to the temporal separation (Δt) when they are participating in a single EM interaction; i.e. $c = \Delta x / \Delta t$. This was first introduced in paper I 4.6 where it was used to define the spatial natural vector **X** in terms of four homogenous components. This was emphasized in paper III [201], where the idea of 'space time integrity' was introduced to constrain the sequential interactions between the same pair of electrons. It is the requirement that the interaction always satisfy this primary condition [202] that is referred to as the "**light-cone**" condition.

Crystal Propagation (Refractive Index)

The idea that a single photon (or wave) traverses a crystal is a massive mathematical simplification of an extended many-body system. At the micro level, this is a series of causal, pair-wise interactions involving many of the electrons in the atoms or molecules of the medium involved. The slower 'speed of light' in a transparent medium is here seen as the result of delays on re-transmission between electrons in different molecules as the momentum exchange is passed along. The time of the delay reflects the various internal interactions (each with its own delay) that may occur in each multi-electron atom in the crystal. The varying speed with frequency (dispersion) reflects the idea that interactions must exactly synchronize with each electron 'at each end' of the interaction pair as well as satisfy the Light-Cone Condition [202] that is limited by the nature and spatial layout of the crystal atoms 'along the optical path'.

In order to estimate the refractive index n of a medium the following simplistic model is offered. It consists of an energetic atom situated above a parallel slice of a non-conducting, transparent crystal of thickness, D. Let the upper surface layer of this crystal define the x-y plane and the origin of the z-axis. The crystal is assumed to be homogenous, consisting of N_m atoms separated by an average (static) distance d in the vertical direction defined by the source and its image on a screen below the lower face of the crystal slab. Thus, approximately, $N_m = D/d >> 1$. The source atom emits a monochromatic pulse of EM energy at a frequency υ defined by the Bohr Rule (see §6.4.2) for its two lowest energy states of its 'optical' electron. If we assume that the slab is in a vacuum and the source is far from any other matter then the first interaction of the source electron will be with an electron in an atom in the surface layer of the crystal. After a delay of $(2 N_d + 1)\,\tau$ seconds then this first electron (labeled x_0) will select another electron in the crystal (labeled x_j), at a depth z_j, for its next interaction. Here, τ is the universal *chronon* and N_d is a characteristic of the crystal atoms that probably varies with frequency and is a small number close to unity. Occasionally, this next selection will not be in the crystal but this will be addressed later under 'Reflection'. This process will be repeated until a final electron in the crystal (labeled x_k) selects an electron in the target screen. As was seen above (see §7.2.3) there are many possible 'optical paths' $[\mathcal{L}_\kappa ; \mathcal{T}'_\kappa]$ even along this simple 1D model. The simplest path, L_1 occurs when x_0 is the only and final crystal electron involved between the source and the target. For simplicity, the source and object separations to the surfaces of the slab will be ignored here (they just add a constant), so: $L_1 = D$, while the 'temporal duration' $\mathcal{T}'_1 = D/c + (2 N_d + 1)\,\tau$, since there is only one 'optical delay'. The next, more complicated path L_2 involves a second electron, at a distance z_2.

$$\therefore\ L_2 = z_2 + (D - z_2) = D \quad \& \quad \mathcal{T}'_2 = L_2/c + 2\,(2 N_d + 1)\,\tau$$

Similarly, $\quad \therefore\ L_3 = z_2 + (z_3 - z_2) + (D - z_3) = D \quad \& \quad \mathcal{T}'_3 = L_3/c + 3\,(2 N_d + 1)\,\tau$

In general, $\quad \therefore\ L_j = z_{j-1} + \ldots + (z_j - z_{j-1}) + (D - z_j) = D \quad \& \quad \mathcal{T}'_j = L_j/c + j\,(2 N_d + 1)\,\tau$

The longest path length L_m occurs when $j = N_m$ when $L_m = D \quad \& \quad \mathcal{T}'_m = L_m/c + N_m\,(2 N_d + 1)\,\tau$

The average temporal duration is: $< \mathcal{T}'_\kappa > = \sum_j \mathcal{T}'_j / N_m = [D/c + j\,(2 N_d + 1)\,\tau\,] = D/c + (N_m + 1)\,(2 N_d + 1)\,\tau / 2$

But, $< \mathcal{T}'_\kappa > = D / V = n\,D / c \quad \therefore\ n = 1 + c\,\tau\,(2 N_d + 1)\,(N_m + 1) / D = 1 + \Lambda_0\,(2 N_d + 1)\,(1/d + 1/D) = 1 + (2 N_d + 1)\,\Lambda_0/d$

Here, $\Lambda_0 = c\,\tau$ is the *luxon* or classical electron radius (see §6.2.2). In many glasses, the inter-atomic separation d is about $3 * 10^{-8}$ cm so that the ratio Λ_0/d is about $4/3 * 10^{-6}$. This implies that the Delay Number, N_d is about $2 * 10^6$.

One possible model for this Delay Number is the fraction γ of the orbital revolution time for an electron in the outer orbit of an atom in the crystal. An order of magnitude estimate uses the Model of the Bohr atom where the revolution time $\mathcal{T}'_B$ is about $1.5 * 10^{-15}$ seconds. In fact, let us re-specify these results in terms of the lowest orbital of the Bohr atom of radius $\mathcal{R}_B$ and period $\mathcal{T}'_B$, where: $\mathcal{R}_B = h / 2\pi\,\alpha\,m\,c \ \& \ \mathcal{T}'_B = 2\pi\,\mathcal{R}_B / \mathcal{V}_B = 2\pi\,\mathcal{R}_B / \alpha\,c$ Define $d = \Gamma\,\mathcal{R}_B \ \& \ \gamma\,\mathcal{T}'_B = (2 N_d + 1)\,\tau$

$$\therefore\ (n - 1) = c\,(1 + 2 N_d)\,\tau / d = c\,\gamma\,T_B / \Gamma\,\mathcal{R}_B = (2\pi / \alpha)\,(\gamma / \Gamma) \approx 860\,(\gamma / \Gamma)$$

Here, α is Sommerfeld's fine structure constant (approx. 1/137) and the factor ($2\pi / \alpha \approx 860$) appears everywhere in atomic physics. The factor (γ / Γ) is the **Atomic Optical Ratio**; it is the ratio of the time that the optical electrons of the atoms of the medium **wait** before each selection T_W ($\gamma \mathcal{T}'_B$) compared to the time for the **transmission** to the next atom T_A .

$$\therefore\ (2\pi / \alpha)\,(\gamma / \Gamma) \ = \ (2\pi / \alpha)\,(\gamma \mathcal{T}'_B / \Gamma\, \mathcal{T}'_B) \ = \ (2\pi / \alpha)\,(T_W\, \mathcal{R}_B / d\, \mathcal{T}'_B) \ = \ (T_W\, c / d) \ = \ (T_W / T_A)$$

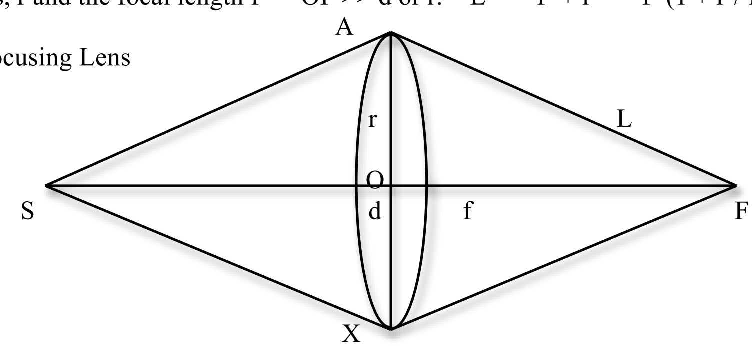
This demonstrates that, at the atomic level, the refractive index is a measure of wasted time (T_W) versus effective time (T_A). The factor ($n - 1$) for air, water and glass are approximately 0.0003, 0.333 and 0.5 respectively so that the 'wasted time' is about 0.02%, 33% and 50% respectively compared with the effective time.

Careful readers will have noticed during this derivation that the assumption was made that each optical path had an equal probability of occurring; this may not be true in reality but variations probably do not alter the magnitude of these results. It will also be noticed that only a maximum of 2 intermediate interactions were considered here, again it is not likely that adding many more intermediate interactions would make any significant, especially because of the finite size of the chronon and the finite atomic separations so that the maximum number of intermediate possibilities is only N_m. This approach can be contrasted with the Feynman geometrization of space when an infinite number of points are imaginable in any finite slab.

Action of a Lens

A similar analysis of the flat mirror situation was used by Feynman in explaining the action of a standard concave lens (each side of radius, R); again the key is to focus on the duration of each of the possible light paths. Without the lens, the longest path is from the source S to each edge A and X (2L), while the shortest path is through the centre-point O directly to the target at the focal point F. Once the lens is in place, the light has now to go through it at a height h above the SF axis, a thickness d. In order to focus the source down to F, then all rays from S must arrive exactly at the same time so they must all have equal travel times. The solution is again a simple problem in geometry. Because the electrons in the atoms in the lens are not exactly coordinated in space on both sides of the lens, there are now many alternate pathways (interactions) for an emission from S to reach F, so the action of the lens is to focus (enhance) the image of S on the screen at F.
Let the lens have a radius, r and the focal length f = OF >> d or r. $L^2 = f^2 + r^2 = f^2 (1 + r^2/ f^2) \quad \therefore\ L \approx f + r^2/ 2f$

Fig. 12 Focusing Lens



$$\therefore\ \Delta t = L/c = n\, d/c + (f - d)/c \ \ \therefore\ L - f \approx d\,(n - 1) \approx r^2 / 2f \quad \therefore\ f \approx r^2 / 2d(n - 1)$$

7.4 DIFFRACTION

Interestingly, Feynman does not spend much time on the phenomenon of diffraction [203], particularly as it was this phenomenon, above all others, that was used to build the support for the wave theory of light. Feynman conducts a very interesting 'thought experiment' where his low intensity, monochromatic light source is blocked from a direct sightline of his photomultiplier (position P) by a screen made from a pair of adjustable blocks. Obviously, when the blocks are quite a bit a part (more than a few wavelengths), the photomultiplier continues to detect the rare photon and when it is moved to the side (position Q), it no longer detects any photons. Feynman attributes this failure to the lengths of the optical paths (from this side of the gap in the blocks to Q) having a sizeable difference in travel time (so his 'timing arrows' cancel against each other) while the paths to P are almost all the same length so the timing-arrows add together constructively. When the blocks are moved closer, "*the light spreads out*" and the detector at Q clicks almost as much as the one at P; thus demonstrating the '*bending of light around corners*'. Feynman explains this as due to the adding together of the timing-arrows in both final situations, as the nearby paths are very similar in length in both cases when the gap is very narrow.

7.4.1 NOT RECOMBINATION

Water and sound waves **do** follow Huygens Principle because there is a material medium for the waves to transfer energy and momentum but the luminiferous æther has ***never*** been found so the wave theory of light is an extrapolation of macroscopic waves in real material media to a microscopic reality without any medium. The one common factor is that the mathematics of waves does not care about the physics of the situation (a medium) but only the size of the wavelength when compared to the width of the slit (or gap); i.e. this is a geometric extrapolation: mathematics once again, not physics.

7.4.2 DISCRETE INTERFERENCE

In order to provide an alternative physical explanation of optical interference, it is necessary to emphasize the critical role of timing differences in the present theory. Also, we must recall an observation made earlier (§2.2.3) that detecting appreciable interference requires that the two-slit separation should be about equal to the wavelength; in other words, the difference in optical paths must be about the same size as the wavelength. Alternatively, it is proposed here that the difference in the travel times between two interfering optical paths is about one complete cycle of the source emitter, even when secondary emission occurs from real electrons near the optical paths.

Explaining Destructive Interference

Unlike macroscopic destructive interference, where two real but opposite forces cancel each other's effect, UET's view of interference is based on the cancellation of possible electron interactions, so that no actual change occurs. This will happen when there are two or more possible interactions possible with the target at a location in the 'dark' region so neither is selected. This will occur when the timing difference is (N + ½) T_R [§6.4.2] then neither source electron is selected for an interaction.

Explaining Constructive Interference

Constructive interference occurs when activity at a given point is determined by two or more influences at similar times – waves are just one (familiar) explanation of this effect. The saturation hypothesis in UET limits the interaction of a target electron to only one other electron at any one of its interaction times. The reality of constructive optical interference means that these observed effects must not be occurring at an instant but over a small temporal duration, much smaller than the time associated with the EM frequency involved. This implies that when only one target electron is involved then each of the possible source electrons are selected serially and the effects are additive on the target electrons velocity, which effectively squares the effect on the target electron's energy difference induced by the double interaction. At low photon intensities, the effect is due more to alternate secondary electrons being actually selected so that more photons arrive in any finite time, such as a single oscillatory period.

Edge Interference

The observed interference effect, near a real edge, is not a proof that light is a wave – only that an oscillatory cancellation effect is occurring. The UET view of a negative fringe is that every location along the fringe B, where there is an electron that could re-transmit the 'excitation' from the source electron at A is at the same 'conflict distance' from an electron C in an atom that forms part of the edge or side. A positive fringe occurs at B when the two separations AB and BC do not satisfy this negative condition and the impulse at B from A is followed in phase by the one from C one chronon later. In this case, secondary re-emissions arise from electrons in the orthogonal (third) dimension at the diffractor (see later).

7.4.3 EXPLAINING INTERFERENCE

Model of Two-Mirror Interference

Fresnel first used interference between two rays as an explanation for optical interference [204] but his success inspired Arago to encourage Fresnel to look for examples of interference that avoided edges that his rival, Biot claimed were the physical source for the interfering secondary rays. Fresnel accepted the challenge and investigated his famous two-mirror source of interference. It is not surprising that his success was used to destroy the rival 'emissionist' theory that needed nearby material to interfere with the direct light as it went by. The following analysis will illustrate that the present theory (that uses much of the mathematical thinking of the ray theorists) is sufficient to provide an explanation without introducing any wave mathematics or thinking. Fresnel crossed rays reflected from two adjoining mirrors and attributed the interference to the rays arising from the images of the same source ('virtual sources') as in the following diagram (based on Buchwald). Again, the explanation here is that two similar paths mutually exclude each other because the source electron cannot decide between which secondary electron (at R or Q) will be the unique, optimal choice for exciting P from S.

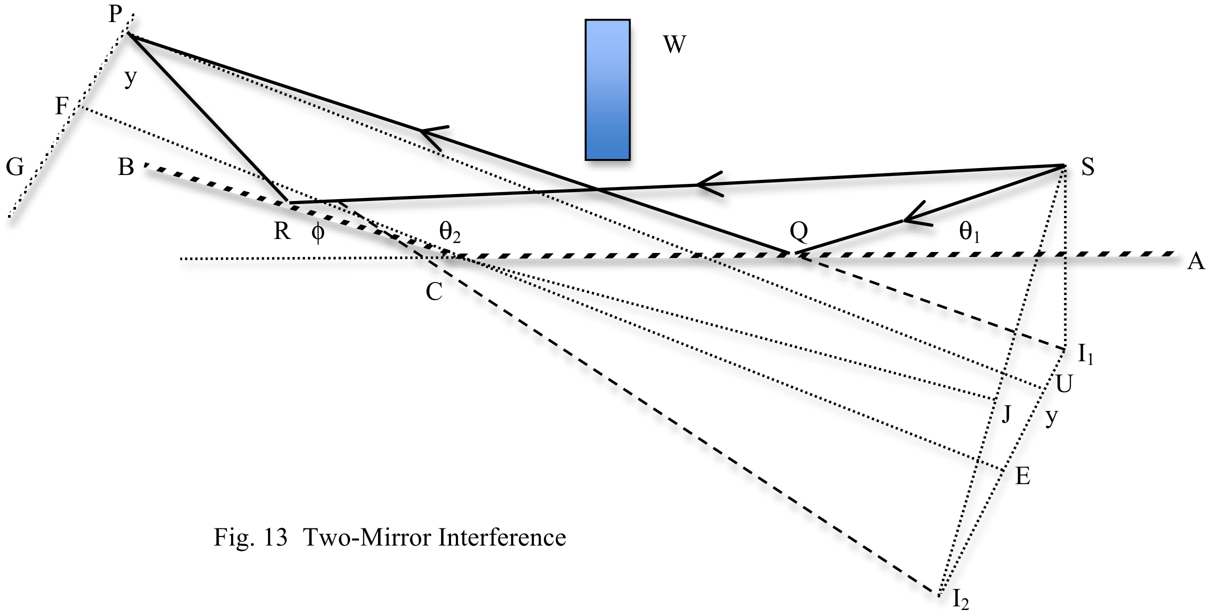


Fig. 13 Two-Mirror Interference

Optics: a) Mirror AC joins to mirror CB, target screen GF, blocking wall W.
b) Source S emits ray #1 SQ that reflects at Q at an angle θ_1 and hits screen at P.
c) Source S emits ray #2 SR that reflects at Q at an angle θ_2 and hits screen at P.
d) Virtual source (image of S in AC) at I_1.
e) Virtual source (image of S in BC) at I_2.
f) Distance in optical paths, $\delta = SQP - SRP$.

Geometry: a) Bisector J of SI_2 (continuation of line BC).
b) Bisector E of I_1I_2; $I_2E = EI_1 = d$.
c) Midpoint of screen F (continuation of line EC).
d) Point U on line I_1I_2 (distance y = FP above E; so that UP parallel to EF, distance $D >> d$).
e) Equilateral triangles $\therefore QS = QI_1$ & $RS = RI_2$.

$\therefore SR + RP = I_2R + RP = I_2P$ & $SQ + QP = I_1Q + QP = I_1P$ $\therefore$ Reflecting paths = Image Paths.

$\Delta\, I_2PU$: $I_2P^2 = I_2U^2 + UP^2 = (d + y)^2 + D^2 \approx D^2$ as $D >> (d + y)$

$\Delta\, I_1PU$: $I_1P^2 = I_1U^2 + UP^2 = (d - y)^2 + D^2$

$\therefore I_2P^2 - I_1P^2 = (I_2P - I_1P)(I_2P + I_1P) \approx \delta\, 2D = (d + y)^2 - (d - y)^2 = 4\, d\, y$ $\therefore y \approx \delta D / 2d$

Let T[x] denote the optical time for the optical path, x and ε is the phase-shift due to reflection (usually taken to be π).
$\therefore \Delta t = T[SQP] - T[SRP] = T[SQ + QP + \varepsilon] - T[SR + RP + \varepsilon] = T[I_2P] - T[I_1P] = n\,\delta / c$

Here, *n* is the refractive index of air (approx. unity). $\therefore y \approx c\, \Delta t\, D / 2d$ & $\Delta t = m\, T_R$ $\therefore y \approx m\, \lambda\, D / 2d$

Fresnel found dark fringes for y satisfying this formula, accurate to several hundredths of a millimeter as m = 1, 2, 3.

Fresnel attributed these dark fringes to wave interference but here it is viewed as due to the total difference in optical times along the original rays that are equal at these special points, so the source electron avoids both as it cannot choose between them. Augustin Fresnel was one of the first scientists to investigate the phenomenon of diffraction from both theoretical and experimental perspectives. This is described, in a historical context, by Buchwald [205]. Fresnel's first attempts involved a binary ray model, where timing differences between two rays explain the observed interference.

This was successful for his explanation of the fringes within the shadow of a very narrow blocking object but failed outside the shadow where one of the rays came directly from the source and the other from the nearest edge. Interference was attributed to the difference in optical 'travel' times between the two rays reaching the observation point; integral multiples of the wavelength λ should produce a bright fringe, while half-integral multiples should result in destructive interference, exhibited as 'dark fringes'.

The following diagram illustrates Fresnel's experiment and theoretical analysis. A source S situated directly above the midpoint F of an opaque object AB, size W, results in a shadow area SS' at a distance EF = D (≈100cm), on a screen on the other side of the blocking object (referred to as the diffractor). Fresnel's source was an extremely narrow hole (<< W) allowing bright sunlight to illuminate the diffractor, which was usually a thread or a wire about 1mm in diameter. The "internal" point P, within the shadow, was considered to only receive rays from each edge at A and B. The "external" point Q, outside the shadow, was considered to only receive rays from the nearest edge (e.g. at A) and directly from the source. The second edge was considered too far away from Q and too oblique to make much of a contribution compared to the other two rays. Let AJ be parallel to EF (extension of line SE) and y = FP and z = FQ. Construct K so that JK = JP $\therefore$ AP = AK. Also, let the difference in the distance in optical paths be $\delta = SAP - SBP = AP - BP$.

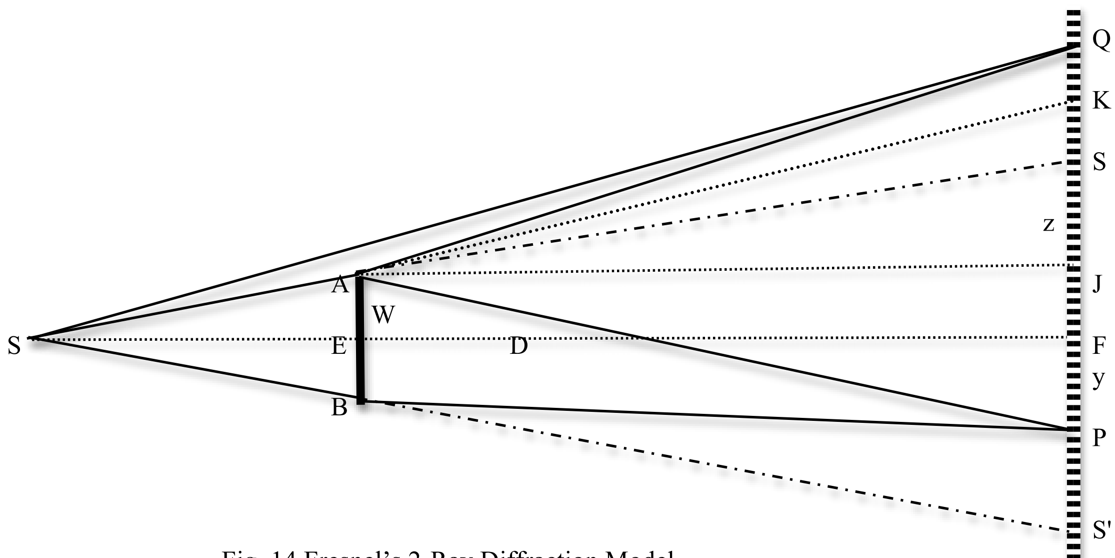


Fig. 14 Fresnel's 2-Ray Diffraction Model.

$$\Delta\, AJK: \quad AP^2 = AK^2 = AJ^2 + JK^2 = AJ^2 + JP^2 = D^2 + (W/2 + y)^2 \approx D^2 \text{ as } D >> (W \text{ or } y)$$

$$\text{Similarly: } BP^2 = D^2 + (W/2 - y)^2 \approx D^2$$

$$\therefore\ AP^2 - BP^2 = (AP - BP)(AP + BP) \approx \delta\, 2D = (W/2 + y)^2 - (W/2 - y)^2 = 2\,W\,y \quad \therefore\ y \approx \delta\, D / W$$

Fresnel discovered that he could observe the fringe pattern directly through a lens without disturbing it thereby avoiding the use of a final screen. He attributed a similar phase change ε at each edge and as the refractive index, *n* in air is almost unity.

$$\therefore\ \Delta t = T[SAP] - T[SBP] = T[SA + AP + \varepsilon] - T[SB + BP + \varepsilon] = T[AP] - T[BP] = n\,\delta / c \approx y\,W / c\,D$$

Fresnel also observed the green minimum (λ = 5176 Å) out of the white sunlight. The first internal minimum was expected at one half-period $T_R/2$ or $\delta = \lambda/2$ so that $y_1 = \lambda\, D / 2W$. Fresnel confirmed these results to an accuracy of 0.01mm. A similar analysis works for the present theory for such expected internal minima. Unfortunately, Fresnel could not get this good agreement with external fringes, indeed they seemed to require a full period difference between the source and the edge ray. This led to Fresnel making arbitrary hypotheses where the edge-ray came from (the "efficacious" ray), some way beyond the physical edge in the open space. Ultimately, this led him to adopt Huygens' principle of secondary waves arising from all points on the wave front, even in locations devoid of matter. In this, the present theory diverges from all these wave theories constructed on Huygens' principle, except when the secondary waves are emitted by real electrons.

Summary of Fresnel's Diffraction Theory

Although Fresnel initially made substantial progress with the ray theory of light (like Young), he was long attracted to the wave theory of light in an æther, as he wrote in 1814:
"*I tell you I am strongly tempted to believe in the vibrations of a particular fluid for the transmission of light and heat." [206]]*

This was reinforced by his formal education in hydrodynamics and the theory of sound at the Ecole Polytechnique. The analogy with water waves is visually overwhelming. Although Fresnel first successfully analyzed the fringes behind a diffractor using pairs of rays, he still used the wave idea of maximum interference (dark fringes) as occurring at half multiples of the light's wavelength. This was the core of his principle of interference [207]. This kinematic principle asserts that a wave impinging on a material body sets its particles in vibration, with the result that each such particle becomes source of secondary radiation that propagates both in the original medium (reflection) and also in the refracting medium, at appropriate speeds. Because the focus is now on the reaction of particles in the media, it is possible to have two impulses cancelling out at a given particle (i.e. interference). Unlike Huygens, this model does not assert that waves propagating in homogenous æther are themselves constructed out of secondary waves; the fronts were initially for Fresnel not yet the loci of secondary emissions but he did view the wave front as a locus of constant phase. In his early work on reflection and refraction, Fresnel always assumed that secondary emission only occurred at the interface between the two media. He also viewed propagation through a medium as condensation (compression) and relaxation that was restricted to a direction perpendicular to the spherical surface, as a similar pressure is felt throughout the surface at every moment. In 1816, Fresnel began to modify this model, as he could not explain interference effects outside the shadow of a diffractor or fixed edge, such as in the single-slit experiments using only his ray theory [208]. Fresnel's first modification involved his concept of the "efficacious" ray [209] where he concentrated all the possible secondary rays 'from beyond the edge' into a single ray; in other words, the origin of the secondary action was no longer the edge of real matter but the empty (or ætherial) space beyond it. This trick added the extra half wavelength path difference that was needed to switch the fringes. The problem was that this solution required the secondary rays to emerge obliquely from the wave front. He tried to retain his original, physical theory by assuming [210] that the edge distorted the pressure gradient back from the real edge into the nearby wavefront. He then divides this wave front into a series of zones, each an extra half wavelength further away from the field point. He creatively posited that due to nearby dynamic pressures, each arc segment produces oblique radiation that by itself can only destroy half the effect of one of its neighbors, the other half is destroyed by the further adjoining arc, except for the segment adjoining the edge. It took Fresnel a further 18 months to drop the efficacious ray and any edge ray and replace them with oblique radiation from **all** points of the front in the æther.

Since segments far from the direct line between the source and the field point (Fresnel called the pole) have a normal that points well away from the direct line to the field point (making an angle θ), Fresnel had to diminish their contribution by a factor, known as the inclination factor, K. Initially, he chose this to be simply the cosine but in 1849 Stokes showed it needed the form $K = (1 + \cos\theta)/2$. Fresnel now persuaded himself that as the field point changed, it received only radiation from two arc segments one remained fixed near the edge of the object while the other was around the 'pole'. Every other part of the front remained 'optically irrelevant', including most of the points between the edge and the pole. Simplified versions of Fresnel's new theory divide the optical front into a number of 'zones' that almost cancel each other's contribution but Fresnel jumped to a full integral approach to this problem. His critical step here was to define his co-ordinate origin at the new 'pole' position. He then decomposed a sinusoidal fluctuation into a pair of related sine waves differing by $\pi/2$; this resulted in his famous pair of integrals that he solved numerically and used to find the first four extrema.

In March, 1817 the French Academy offered a prize for a memoir on diffraction; ironically, at least two senior members (Laplace and Biot) were hoping for a ray-based submission but their rival, Arago [211] was aware of Fresnel's progress. Only one other submission was received, while Fresnel's entry is usually referred to as the famous *Memoire Couronné*. He began his submission with a critique of the ray theory as being unable to explain diffraction without several, extra implausible hypotheses. This did not convince his critics (especially Poisson) but all were impressed by Fresnel's massive theoretical analysis and precise experimental detail. This work did not mention the efficacious ray (even though it had helped him explain the observations) but stated that: "diffraction cannot be explained only by rays that touch the edge of bodies". He indirectly introduced Huygens principle [212] when he wrote that diffraction needs "an infinity of other rays, separated from these bodies by finite intervals, that are diverted from their original directions to form the fringes." He used his integral method for both the single edge (semi-infinite plane) and the single-slit. Once again, the very accurate agreement between experiment and theory was used by Fresnel to justify the validity of his theory but the skeptics in the Academy remained unconverted to the wave theory.

Poisson pointed out that Fresnel's theory predicted a small bright spot in the centre of the shadow behind a small, circular disk. Arago himself then found this effect, known as the Poisson/Arago Spot. The trick was to draw a series of zones, differing in distance from the field point by half wave lengths; at great distance, these zones are almost the same area so Fresnel felt they contributed equally to the net effect at the observation point. If this point saw an even number of zones then they all cancelled out and a minimum resulted but if the observation point was shifted a little then we see the effects of an odd number of zones and a local maximum will be observed. [213]

Even Thomas Young had difficulty accepting the Huygens/Fresnel wave theory [214] because he thought that: "*secondary waves would rapidly cancel each other out in a very short space*." Fresnel's rebuttal was then based on a material analysis of Huygens' principle, which is a "*rigorous consequence of the coexistence of small motions in the vibrations of flui*ds." Poisson challenged this response, claiming that: "*Fresnel's integrals require certain dependencies and that these are not justifiable if light obeys the same kind of laws that govern the propagation of waves*." Unfortunately, Fresnel's position requires an intricate analysis of the 3D scalar wave equation that Kirchhoff was only to develop in 1883. LaPlace and Poisson both disagreed with the use of Huygens' principle for all wave propagation on the grounds that there was no evidence that particles in the oscillating medium behaved as needed; in particular, the inclination factor had to be an exceedingly rapid function of angle, which would prohibit the kind of lateral radiation needed by Fresnel. This critique was grounded in the belief that light pulses required propagation close to the normal of the wave front (i.e. like rays). This basic disagreement reflected the **metaphysical** dispute around the status of the concept of 'light ray'. Even as late as 1939, the authors had to admit [215] that pulses could only be analyzed using the dynamics of the medium in which the waves occur.

7.4.4 UET MODEL OF NEAR-EDGE DIFFRACTION

This section offers an alternative theory of near-edge diffraction that is similar to Fresnel's mathematics but differs in the physical explanations. Fresnel followed Huygens and imagined that the interference at the field point P was due to light arriving from different segments of the secondary wave front near the obstructing surface (diffractor). The UET theory rejects the origination of any light from any point ***unless*** occupied by an electron at the time of emission. Real surfaces are always identified that play the role of the secondary sources; the phase differences still obey the Fresnel interference rules.

Single-Hole Diffraction Theory

In the single-hole model, the secondary surfaces are identified as **in** the walls surrounding the hole, say in a sheet of tinfoil, which has a finite thickness, D of about 0.1 mm. This means that the wall of the hole consists of about 200,000 atoms. It is the electrons in these surface atoms that scatter the initial impulse from the source to the field point (at P). Such secondary scattering does not have to obey the reflection laws, which only apply to large collections of synchronized scattering. In this case, each event is a single, intermediate event in the optical paths from the source (at H) to the final absorption at P.

Fresnel created a series of concentric circles on the wave front, differing in distance to the field point by half wavelengths. Each circle defined a 'zone' that was of approximately the same surface area. The secondary waves from these zones almost cancel those from nearby zones whose phases differ by one half period. Fresnel summed these contributions from all of these zones and found that the total was either half the sum or half the difference of the contributions from the first and last zones. Usually, the contribution from the last zone is ignored (due to the obliquity factor), leaving half the first zone as the equivalent, net contributor.

Optics:
1) Pinhole source at H. 2) Field point at P.
3) Gap in screen, EE , width 2W. 4) Spherical Wave front E O E' , radius a, centre at H.
5) Cylindrical hole surface EF and E'F' with axis HP, depth D.
6) Secondary source electrons at U and V.

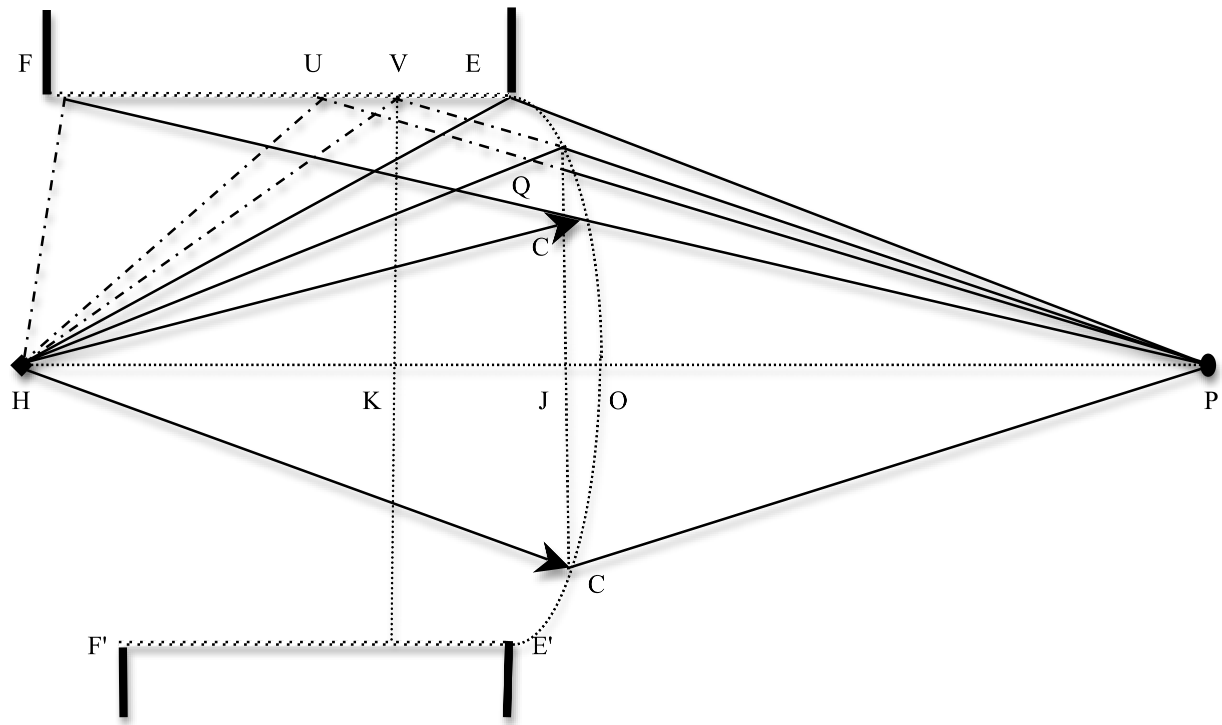
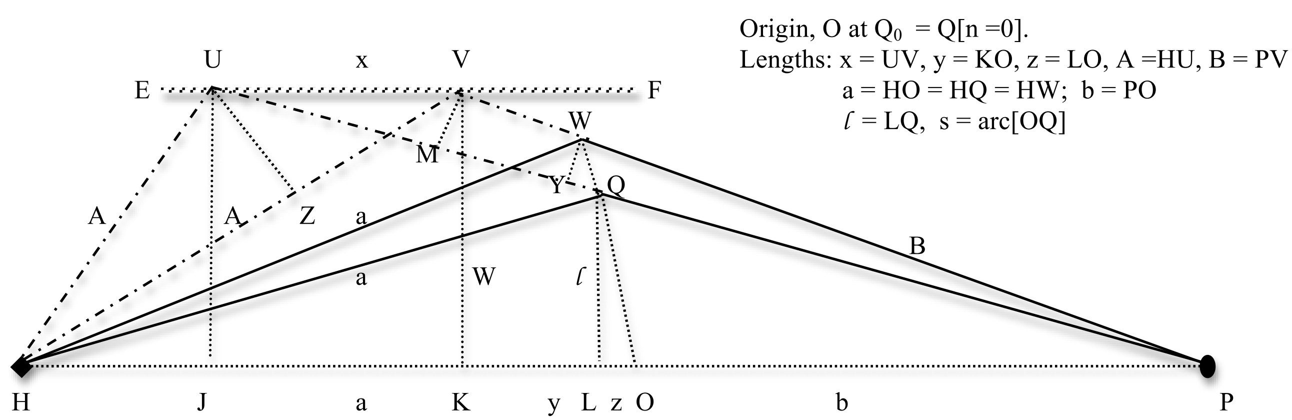


Fig. 15 Fresnel's Circular Diffraction Model.

We will now focus on two adjacent rays HUP and HVP (exaggerated) to determine the detailed geometry.



Geometry:

a) Set of ½ wavelength zone boundaries, drawn from P to Q; PQ = $b + n\,\lambda/2$ [n=0,1, …, m]
b) Next ½ wavelength zone boundary, drawn from P to W; PW = PQ + $\lambda/2$
c) Line PQ extended backwards (straightline) to intersect wall EF at point U.
d) Line PW extended backwards (straightline) to intersect wall EF at point V.
e) Line UH of length A and VH divided at Z, distance A from H.
f) Line QU divided at M, distance B = PW.
g) Line QU divided at Y, distance B.
h) Point K directly perpendicular below V, J below U, L below Q, all on axis PH.

Note: the optical paths HUP and HVP are not reflections off the hole wall at U and P but subsequent interactions with an electron at P. The lines are not rays but possible optical paths, i.e. straight-line interactions. There are no light particles.

The Sagitta formula in Δ HQL: $HQ^2 = HL^2 + LQ^2 \;\therefore\; a^2 = (a - z)^2 + \ell^2 \;\therefore\; 2\,a\,z = \ell^2 + z^2 \approx \ell^2 \;\therefore\; z \approx \ell^2/2a << \ell$

$$\Delta\, PQL:\; PQ^2 = PL^2 + LQ^2 \;\therefore\; (b + n\,\lambda/2)^2 = (PO + z)^2 + \ell^2 = (b + z)^2 + \ell^2$$

$$\therefore\; b^2 + n\,\lambda b + (n\,\lambda/2)^2 = b^2 + 2bz + \ell^2 + z^2 = b^2 + 2bz + 2az \;\;\therefore\; n\,\lambda b \approx 2z\,(a + b) \;\;\therefore\; n\,\lambda \approx \ell_n^{\,2}\,(a + b)/a\,b$$

The lowest ray ($n = 1$) goes through Q_1 & extended to U_1 that must be on EF, so $U_1F < D$, while $\angle PU_1F = \beta_1$ & $\ell_1 \approx PQ_1$

$$\therefore\; \tan\beta_1 = W/D = \ell_1/z_1 = 2\,a\,\ell_1/\ell_1^{\,2} = 2a/\ell_1 \;\;\therefore (D/W) \geq 2a/\ell_1 \;\;\therefore\; D \geq 2\,W\,a/b$$

Since: $HO = Hl + LO = HL + z = a = HJ + JK + KO = HJ + x + y \;\;\therefore\; HL = a - z \;\;\therefore\; HJ = a - x - y$

$$\therefore\; \Delta\, HVK:\; HV^2 = VK^2 + HK^2 = W^2 + (a - y)^2 \qquad \therefore\; \Delta\, HUJ:\; HU^2 = UJ^2 + HJ^2 = W^2 + (a - x - y)^2$$

$$\therefore\; \Delta\, PUJ:\; PU^2 = UJ^2 + PJ^2 = W^2 + (b + x + y)^2 \approx b^2 \quad \therefore \Delta\, PVK:\; PV^2 = VK^2 + PK^2 = W^2 + (b + y)^2 \approx b^2$$

$$\therefore\; HV^2 - HU^2 = HK^2 - HJ^2 = x\,(2b + 2y + x) \approx 2\,a\,x = (HV - HU)\,(HV + HU) \approx (HV - HU)\,2a \;\;\therefore ZV \approx x$$

$$\therefore\; UP^2 - VP^2 = JP^2 - PK^2 = x\,(2b + 2y + x) \approx 2\,b\,x = (UP - VP)\,(UP + VP) \approx (UP - VP)\,2b \;\;\therefore UM \approx x$$

Instead of Fresnel's optical path HWP and HQP we now choose $R_1 =$ HUP and $R_2 =$ HVP. So, the path difference:

$$\delta = R_2 - R_1 = (HV + VP) - (HU + UP) = (HV - HU) - (UP - VP) = VZ - UM \approx x - x = 0$$

Fresnel decided that the observed destructive interference at P from a source at H was due to Huygens' secondary waves that were re-emitted from the **empty** space on the wave front at W and Q. The present theory states that the source at H decides that interacting <u>with electrons in the wall</u> at U and V produce no eventual difference when they try to then reach common point P. It is the principle of Saturation-Indifference over both **total** paths that determine that H does **not** interact with either U or V. So, now Fresnel's wave front arc WQ maps one-to-one with the wall strip UV. Equivalently, Fresnel's n^{th} half-wave zone maps to the annulus of width x_n described on the ***interior*** of the wall of the hole; hence the name of this interference mechanism: "**wall-diffraction**". Varying the screen distance (b) will produce equal path lengths from two wall electrons corresponding to adjacent Fresnel 'zones' if the zone-edges are multiples of half wavelengths (destructive interference) or unequal path lengths from two adjacent 'zones' if the zone-edges are odd multiples of quarter wavelengths (constructive interference). The shape of the hole is predicted to determine the observed interference effects.

Circular Aperture

When the source hole is replaced by a screen containing a larger circular aperture, similar results are found. The present theory again emphasizes the role of the wall forming the hole. If the hole diameter covers all of the first zone boundary then all of the electrons in the wall corresponding to the points in the second zone can make a contribution during one complete period with a much brighter result (constructive interference). But if the diameter exposes the first two zones, then the wall electrons will all effectively cancel their contributions, as shown above, and almost no interactions will get through to the field point, P. Varying the distance of the screen to the whole will accomplish the same results, alternating between dark and bright. Similarly, when the field point is 'off-axis' similar results will hold producing a series of bright and dark rings around the axial point on the screen. The key role of the edge of the disk is demonstrated by the rapid disappearance of the spot when the disk deviates even in a small way from perfect circular cross section, such as limited roughness.

Fresnel Zone Plate

If a circular screen is designed to block off every alternate half-zone then only the reinforcing zones contribute to the very bright final image. This is known as a Fresnel zone plate and it can act as a lens. Sub-zone selections are also possible.

Poisson/Arago's Spot

When the hole is blocked by a circular disk placed somewhere <u>between</u> the 'source' hole and the screen then it is possible to see a bright spot in the center of the shadow. This is known as the Poisson or Arago (or sometimes, Fresnel) spot. In this case, it is both the wall electrons and the electrons in the edge of the disk that co-operate to produce the observed effects.

The wall electrons contribute possible optical paths over a conical range of possibilities, while the disk edge electrons can then come into play in pairs, as in Fresnel's 2-Ray Diffraction Model (analyzed above).

This spot played an important role in convincing scientists (especially French optical specialists) that light did not consist of particles, as Newton had proposed, but waves following the Huygens' hypothesis. Poisson studied Fresnel's theory in detail and of course looked for a way to prove it wrong, being a supporter of the Newtonian particle-theory of light. Poisson thought that he had found a flaw when he argued that a consequence of Fresnel's theory was that there would exist an on-axis bright spot in the shadow of a circular obstacle, where there should be complete darkness according to the particle-theory of light. This spot is not easily observed in every-day situations, so it was only natural for Poisson to interpret it as an absurd result and that it should disprove Fresnel's theory. However, Fresnel's sponsor, Arago decided to perform the experiment in more detail. He molded a 2 mm metallic disk to a glass plate with wax. To everyone's surprise, he succeeded in observing the predicted spot, which convinced most scientists of the wave-nature of light. It is thus a great example of a so-called "crucial experiment". Once again, this illustrates how such experiments illustrate the absence of a suitable theory rather than the unique, indisputable truth of a theory that is compatible with the observations.

Fresnel's Straight-Edge Diffraction

When a monochromatic source shines though a small hole ('pin hole') towards a straight edge positioned in front of a screen, a variation in intensity of the light is observed in the direct beam area above the shadow line on the screen. Fresnel again analyzed this situation in terms of a wave front, but now at the screen, taking a cylindrical (rather than circular form) that is divided into parallel strips, which are successively one-half wavelength farther from an observing field point on the axis, P. Fresnel constructs a direct line between P and the center of the hole H such that the line PH divides the zones into those between the edge and the pole M (the intersection of PH with the cylindrical wave-front) and those above the pole. The zones below the pole partially compete in their contributions with those from the exposed zones above. These are normally calculated using a geometric construction known as Cornu's spiral.

In the present theory, only a subset of the electrons in the wall of the source hole can reach the observation point and the electrons in the edge of the straight-edge obstruction. The totality of possibilities will contribute to the observed results. This is another example of 3D geometry that will not be developed further at this time.

Fresnel's Single-Slit Diffraction

The present theory can be readily extended to the well-known case of a single slit, illuminated by monochromatic light emerging from a narrow source parallel to the diffracting slit. Here the walls behind the source-slit play the same role as secondary sources of electron re-emission and the two edges of the slit double up the contributions from the edges. When a monochromatic source shines though a narrow slit then straight diffraction fringes appear on the screen. Fresnel analyzed this situation in terms of a cylindrical wave front that is divided into strips parallel to the slit, which are successively one-half wavelength farther from an observing field point on the axis. The areas of these strips are proportional to their widths and these widths decrease rapidly away from the polar axis, as in the single straight edge case. The maximum intensity occurs when the center of the wave front is on the axis as wall electrons all around this axis can contribute, as can those all along the two edges of the diffractor slit.

Young's Double-Slit Experiment

Thomas **Young** first performed his famous experiment in 1801 by allowing bright sunlight to pass through a pinhole H and then, at a considerable distance away, through two closely separated pinholes, S_1 and S_2, about 0.5 mm apart. He found that a symmetrical pattern was formed on a further distant screen, which he interpreted as interference between two spherical waves emerging from S_1 and S_2. Later versions, replaced the pinholes with very narrow parallel slits, while H also became a similar parallel slit illuminated by monochromatic light. The resulting pattern on the screen seemed to be a composite of the patterns from a single slit but now multiplied together. The fringes become more widely spaced when the secondary slits are closer together (e.g. 0.2 mm), while red light produces wider fringes than green light.

The use of harmonic analysis (i.e. sine waves) provides a very simple 'explanation' of the phenomenon, as can be seen in the differences in optical path lengths in the following diagram.

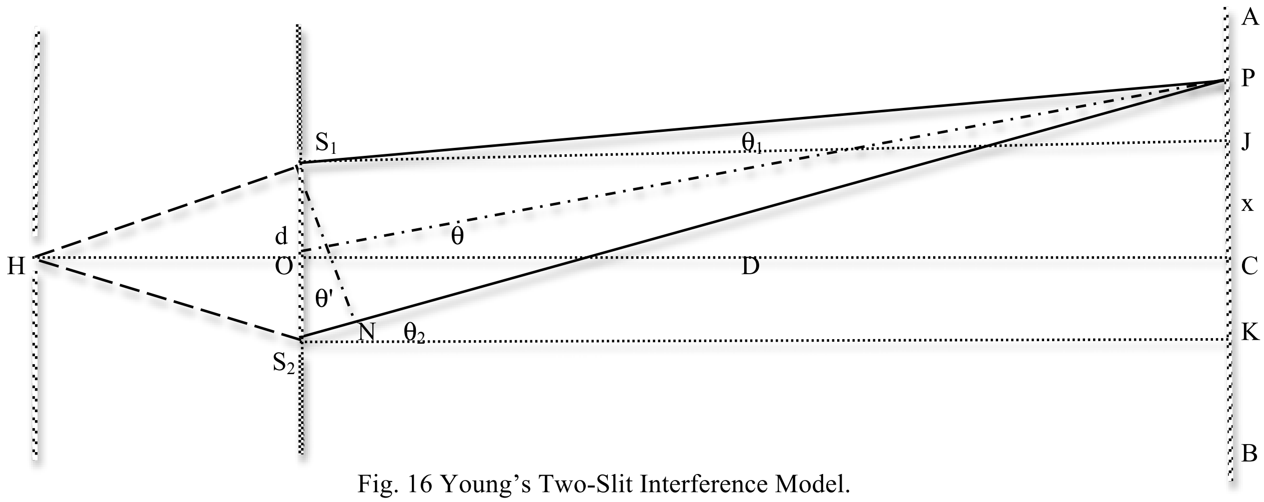


Fig. 16 Young's Two-Slit Interference Model.

Defining the field point displacement $x = PC = PJ + JC = PJ + d/2 \;\therefore\; PJ = x - d/2$ & $JK = d$ & $\Delta = S_2P - S_1P$

$$\therefore S_2P^2 = S_2K^2 + PK^2 = OC^2 + (KJ + JP)^2 = D^2 + JP^2 + JK^2 + 2\,KJ\,JP \approx D^2 \;\therefore\; S_1P^2 = S_1J^2 + JP^2 = D^2 + JP^2 \approx D^2$$

$$\therefore S_2P^2 - S_1P^2 = JK^2 + 2\,JK\,JP = d\,(d + 2x - d) = 2\,d\,x = (S_2P - S_1P)\,(S_2P + S_1P) \approx \Delta\,2D \quad \therefore \quad \Delta \approx x\,(d/D)$$

$$\therefore \Delta \approx d \sin\theta = S_2N \text{ [the usual approximation of assuming: } \theta' = (\theta_1 + \theta_2)/2 \approx \theta.]$$

Detailed measurements confirm that the fringes are equally spaced where the difference in separation Δx varies directly with the screen distance D and inversely proportional to the slit separation d and directly proportional to the wavelength λ.

It is the unique and powerful property of harmonic functions that their sums always produce another harmonic function that leads to the "wave" idea of superposition of contributions; this is no more than angles around a point are 2π cyclic; e.g.:

Let $Y_1 = a \sin[(\omega\, t - k\, x)]$ & $Y_2 = a \sin[(\omega\, t - k\,[x + \Delta])]$ & using: $\sin A + \sin B = 2 \cos[(A-B)/2] \sin[(A+B)/2]$

$$\therefore Y_1 + Y_2 = 2a \cos[k\,\Delta/2] \sin[\omega\, t - k\,(x + \Delta/2)] = Y = Z\,Z^* \quad \{p.271\}$$

Thus, the addition of two similar sine waves, differing only in their phase Δ, will produce a single sine wave with its phase shifted by $\delta = k\,\Delta/2 = \pi\,\Delta/\lambda$ and its amplitude multiplied by $2\cos[\delta]$. When $\Delta \ll \lambda$ then $\cos[\delta] \approx 1$ while if $\Delta \approx (n+1/2)\,\lambda$ then $\cos[\delta] \approx 0$. So the phase difference of two sine waves alone determines if constructive or destructive interference. This process can be repeated indefinitely by adding more and more sine waves; this is the mathematical basis of Fourier analysis.

Young also discovered that he could **not** produce interference if light from two different sources was directed separately at each of the slits. Only a coherent source, such as a ***single*** electron as in this theory, can produce interference.

The UET theory achieves the same result but interprets the optical paths as emerging from within the walls of the slits (as in the single hole analysis above), rather than from secondary waves emerging from the two slits. In the double-slit situation, each source electron is faced with choosing between 4 possible optical paths; equivalently, which of the 4 possible electrons in the walls of the two slits will be chosen as an interaction partner for subsequent re-emission to the target electron at P. Since the screen distance, D is vastly larger (at least 1000 times) than all the other spatial differences, no observable differences will be detectable between these two theories. Sommerfeld [216] analyzed diffraction in terms of Maxwell's EM theory along with boundary conditions of the diffractor, idealized as infinitely thin with perfect reflectance. Sommerfeld found that a cylindrical wave originated at the edge that interferes with the direct wave producing fringes, as Young thought.

7.5 THE UET RADIATION MODEL

Validity of Classical EM Theory

Maxwell created a differential (infinitesimally localized) model of the integrated, macroscopic collective effects that had been summarized as integrated (flux) laws that were based on macroscopic measurements in the forty years since Oersted. Maxwell's EM theory (CEM or classical EM) was not about sources (or even absorbers) but was restricted to "the place between" – usually empty space. The modern version of CEM has been shown to be a blend of Maxwell's Equations and Helmholtz's physical model of continuous electric charge density [2]. CEM is only appropriate to situations involving either large numbers of electrons (at least, several million), 'long' time intervals (at least, thousands of *chronons*) and significant spatial separations (at least, hundreds of atomic diameters). As a collectivist theory, CEM cannot be used to predict the dynamics of small numbers of electrons (less than a hundred) interacting frequently at close separations; e.g. atoms, molecules, nuclei. At best, CEM can estimate average mesoscopic results. It is **not** a suitable basis for quantization.

Electro-Kinetic Momentum

Maxwell's 'Dynamic' theory was primarily a theory of magnetism [2]. Maxwell focused on the concept of electro-kinetic momentum (now called the vector potential) [217] viewed as the impulse of the electromotive force generated by the removal of all the source magnets and currents. Maxwell used Neumann's concept of a vector potential $\underline{A}$ but he interpreted it as the **density** of electro-kinetic momentum (that was produced by any system of magnets and/or electrical currents) to comply with Faraday's views on the reality of the magnetic field as æther strain. The key hypothesis in the new statistical CNV model of classical EM is that the scalar potential (or EM energy of position per unit charge) at any point in space and time ($\phi[t; \underline{x}]$), can be represented mathematically as the temporal part A_0 of a corresponding Voigt vector, called (in honor of Maxwell) the CNV Electro-kinetic Momentum [218] or the CNV Potential $\mathbf{A}$. The linkage here is that the micro impulse $\Delta\underline{I}$ is related to the local change in the 3D vector part of the CNV Potential $\underline{A}$ via the universal electron charge e; i.e. for each electron: $\Delta\underline{I} = e\, \Delta\underline{A}$.

Heaviside's introduction of the magnetic field is viewed here as a mathematical macro-scale epiphenomenon that plays no role here [219] in the present micro theory. It is not a coincidence that experiments confirm that it is the electric vector that affects photographic plates and causes fluorescent effects. It is also believed that it is this component that activates signals in the retina of the eye. Feynman also pointed out that the rate that the electron increases its energy is only due to the electric force part of the Lorentz force; i.e. $d\mathcal{K} / dt = e\, \underline{E} \bullet \underline{v}$. This implies that the magnetic field only contributes to changes in direction of the target electron, not its speed, as we would expect for a transverse interaction.

No 3D Radiation (except Statistically)

As a material theory, the focus here is always only on the two points in space where two electrons are located at the two times of each of their mutual interactions. This focus leads to the hypothesis that each interaction between the two electrons is only directed between them and not 'broadcast' through the universe, as is the case with all single-time field theories.

All electron properties are introduced in terms of the interaction between two electrons – this theory is inherently relational and rejects the 'egotistical' view of the single particle. Einstein's theory has been called 'relative' but the focus was always on the singular field point (on the wave front); it was only relative to abstract 'observers' who sit at the centers of arbitrary inertial (mathematical) frames of reference. In the present, saturated theory, electron 'observers' at the origins of these two reference frames **cannot** interact simultaneously with the same target electron, as is assumed in SRT, and so cannot observe.

UET is consistent with CEM since electrons are viewed as always moving at constant velocity, except at interaction points, so that 'radiation' only occurs when the electron instantaneously changes its velocity. The 'radiation' is ray-like and limited to a line-of-sight exchange of momentum between the two electrons involved. Only when large numbers of interactions are involved will they appear to be spread in all directions (isotropic).

Hertz: Fluctuations, not Waves

It is important to note that the famous 'spark' experiments of Hertz did not prove that EM situations were 'wavelike' but only that EM is a time-varying phenomenon that could undergo 'interference'. The wavelengths used by Hertz in 1888 (about 3m) were enormously larger than those found with visible light emitted by atoms (about 10^{-6} m) [220].

Far-Zone, Loss-less Propagation

In CEM, the radiation solutions (the 'far zone' approximation) only retain terms, which vary inversely with distance (1/r), such as the magnetic $\underline{B}$ and transverse electric $\underline{E}_T$ force-density fields; dropping higher order terms, like the longitudinal (or radial) electric $\underline{E}_R$ force-density, which varies as $1/r^2$. The power (or rate of energy flux, ΔP) radiated into a small solid angle $\Delta\Omega$ defining a small element of the spherical surface at that distance ($\Delta\underline{\sigma}$) is given by: $\Delta P = \underline{S} \cdot \Delta\underline{\sigma}$ where the energy flux is the Poynting vector, $\underline{S} = c\, \underline{E} \wedge \underline{B} / 4\pi$ varies like $1/r^2$ but $\Delta\sigma = r^2\, \Delta\Omega$ so ΔP is independent of distance and flows outwards through a small solid angle without being attenuated by distance, eventually absorbed by encounters with remote, real charges. In UET, the set of EM interactions originating from a small group of remotely interacting (i.e. 'radiating') electrons, centered within a small solid angle, is coherent until they meet another group of closely, clustered remote electrons, where a loss-less transfer of energy and momentum occurs.

This research programme and particularly this paper (especially in section 3.4.2) have frequently criticized Maxwell's theory of electromagnetism and its perceived basis for Hertzian radiation (§6.4.5). It is important to realize that the present theory sees itself as a microscopic extension of Maxwell's theory but with the following major **differences**. Maxwell's theory was constructed on continuum microscopic fluctuations (field theory) in a universal 3D medium (the æther), where an electric force density was defined everywhere at a single universal time. The UET only considers interactions between pairs of electrons when no other choice is appropriate and even then, the interaction manifests itself as reciprocal impulses (not as continuous forces) on a cyclic multiple of the tiny time interval (the *chronon*) at **two** different times at each electron. In the present theory, there are no secondary emissions from empty space but only from locations occupied by electrons. For remote separations, the UET impulse (§6.2.3) only acts perpendicular to the direct line of sight between two interacting electron; i.e. it acts discretely, somewhat like a discontinuous transverse electric vector in the Maxwellian radiation theory.

MMX Null Result

The MMX interferometer does not change any of the path lengths or retransmission delays when the instrument is rotated relative to the fixed stars, so there will be no change in the observed interference effects; only models of light seen as a traveling object (like Maxwell or Einstein) would expect to see a shift. The Lorentz transformation is then invented to alter the space and time separations to 'explain' why no shifts are seen. The real world is much simpler: "Space is passive".

7.6 POLARIZATION & OPTICAL ACTIVITY

Most Nineteenth Century physicists, after examining the mathematical descriptions of interference and diffraction, were led to conclude that light is a wave phenomenon with a well-defined wavelength. However, these effects could not determine whether the undulations were longitudinal or transverse or whether the vibrations were linear, elliptical or whatever. Worse, they cannot determine if these temporal variations are propagated locally across space or occur as action-at-a-distance (ADA). One of the major successes of Maxwell's Theory of electromagnetism was to identify transverse waves propagated in the æther with light. The agreed value of velocity of these waves between theory and experiment was considered the clinching argument. It was one of Fresnel's major contributions to explain the polarization of light in terms of transverse polarization but there were several other experiments that seemed to confirm this impression. The present section will show that the ADA theory can also provide a satisfactory explanation for all these effects, again putting the certainty of the wave theory in doubt.

7.5.1 EXPLAINING POLARIZATION

In an earlier section herein (§6.2.2) it was shown that quantizing the kinetic and dynamic actions when two electrons are interacting across 'far' spatial separations reduced the longitudinal impulses to insignificance and required that a transverse component emerge to make the necessary contribution in terms of opposing, transverse impulses of fixed magnitude (*mb*). Since these impulses only occur at the 'sending' and 'receiving' electrons involved in their mutual interaction then an alternative mechanism arises at real material locations rather than Maxwell's oscillations in empty space (or æther). As such, the EM explanations for optical effects can be carried over to the present theory, as long as the appropriate electrons are first identified. This is straight forward, as all the observed effects only occur when light interacts with real matter.

The key to understanding polarization is to consider ordinary light as always consisting of mixtures of transverse activity that are separated by various physical interventions. In particular, polarization becomes manifest only after light has had an opportunity to undergo such an interaction, which then leaves the polarized fractions distinct. This is particularly evident when light propagates through (or rather here: interacts with the electrons in) certain types of crystals.

The similarities described above (between the present theory and Maxwell's EM theory) are sufficient to explain the physical mechanisms of reflection, transmission, dispersion and polarization. The only difference is that the transverse impulse only occurs at each of the two electrons in an interaction. However, when one realizes that the only real effects in Maxwell's theory in material media only occur where the electric vector is experienced by electrons in the atoms of the medium then the only actual difference is between the finite impulse and the continuous electric force vector but this is too brief to be detected in most experiments. Maxwell was never justified extending his 'displacement' current from real media to the empty vacuum.

Polarization is now viewed as induced oscillations (in the transverse plane) combined with finite delays at each atom for absorbing and retransmitting the excitation between electrons. Secondary electrons are constrained to move only in certain 2D directions and this distortion remains in the "light ray" thereafter. It has been discovered that optically active crystals are made up of atomic layers that are twisted slightly one from another. In crystalline quartz, columns of silicon and oxygen atoms occur in spirals forming planes producing rotation along the optic axis of the crystal. Max Born used Maxwell's theory to explain optical activity in dielectrics (where it works well). An external electric field (or here, transverse impulses) produces a separation of electrons at the atomic level, polarizing the medium parallel to the electric vector. Born modeled this with the ubiquitous harmonic oscillators coupled together, in asymmetric sets of four, by electric forces. Condon later showed that these results can be obtained [221] with a single-oscillator model. Biot in 1811 was the first to discover that many organic liquids could also rotate the plane of vibration; here the complex molecules behave as a small crystal with its own optic axis.

Feynman provides an alternative description of polarization, claiming that photons are polarized in the 3 spatial dimensions and also the temporal one. He also claims that the temporal polarization is cancelled by the longitudinal one for real photons traveling a long distance (here, it is the diminution of the longitudinal impulse at 'far' distances) while, for 'virtual' photons going between a proton and an electron in an atom, he claims [222] it is the temporal component that is the most important.

7.5.2 EXPLAINING EM OPTICAL ACTIVITY

Disturbing the Source

Lorentz quickly proposed a theory to explain the Zeeman effect based on his electron theory of matter and the assumption that electrons are responsible for light - a view shared by the present UET. The presence of other electrons that are usually considered to be the source of magnetic effects will also interfere with the original source electron motion, especially when one considers the impact of the present Saturation hypothesis. In his original theory, Lorentz assumed that the electrons in the source are revolving in circular orbits oriented at random in space; this is equivalent to 2/3 of them revolving in circular orbits in the plane perpendicular to the axis of the 'magnetic field'. One direction is speeded up while the opposite is slowed down as per Faraday's law of induction. This was the source [223] of all electron interactions as shown in paper III. The Stark effect is a similar interference with the original dynamics of the source electrons by very large aggregates of <u>nearby</u> electrons that interact via the more powerful longitudinal impulses.

Disturbing the Medium

Just as 'third-party' (external) aggregates of electrons can interfere with the undisturbed dynamics of the source electrons they can also disturb the electrons in the intermediate medium that is passing on the impulses via secondary electrons in the medium. These electrons can alternate (over time) with earlier electrons in the optical path and the disturbing electrons. In particular, in the absence of these external influences the medium will exhibit normal activity, such as resonance frequencies where absorption takes place. These resonance frequencies will be affected, as in the Zeeman effect, and this alters the values of the complex refractive indices for the left and right circularly polarized propagations. These effects expand as the time for the impulse transfers increase, i.e. with exposed path lengths. Again, it is important to emphasize that these effects require a real, material medium but, in EM theory, should still have some effect on the fields passing through empty space.

7.7 ABERRATION & DOPPLER EFFECTS

There are three experiments involving light that have been used to justify Einstein's special theory of relativity (STR). We do **not** include the famous Michelson-Morley experiments because it would seem that Einstein constructed his mathematics to explain that experiment by redefining the space and time intervals to comply with the observed constancy of light speed.

Aberration Results

Bradley's first-order aberration result is explained here as the differences in times between the emission event in the nearby star and the possible reception points on the Earth's orbit corresponding to zero or finite tangential velocity. Airy's no-difference result occurs because the time-difference introduced by the telescope being filled with water or not is just too small to be measured compared with the other (planetary) time differences involved.

Fresnel Drag

In 1859, Fizeau conducted another of his famous experiments to measure the speed of light - this time directing the light beams through rapidly flowing water as in a Rayleigh refractometer. Using two tubes 150 cm long filled with water flowing at 700 cm/sec, Fizeau found a shift of 0.46 of a fringe when the flow direction was reversed. This corresponds to an increase in the speed of light in one tube and a decrease in the other of about half of the velocity of the water. These results were then confirmed by Michelson, who modified his own interferometer. Initially, these results were interpreted in terms of Fresnel's theory of æther drag that assumed that the density of the æther in a medium exceeds that in a vacuum by the ratio n^2. He then showed that the æther is effectively dragged along with a moving medium with an effective speed: $\mathrm{v}\,(1 - 1/n^2)$, where v is the speed of the medium and n its index of refraction; the factor $(1 - 1/n^2)$ is referred to as Fresnel's drag co-efficient. This result has been re-derived from the SRT using the relativistic compounding of two velocities although this contradicts a major postulate of SRT that light always travels at a constant speed to all observers (here, always between two electrons).

The present theory does assume that the electrons in the moving media take on the average speed of the medium so that there is actually a longer duration for interactions to propagate between these electrons compared to when the medium is at rest, relative to the fixed laboratory equipment. It is not æther but real matter that is moving relative to the laboratory.

Relativistic Doppler Effect

The classical Doppler explanation is modified in the SRT by replacing the classical time period by one expanded by the application of the Lorentz factor $\mathcal{L}[\mathrm{v}]$ (§4.5.2). Since Earth-bound experiments introduce any speed v that is much smaller than c then the Lorentz factor can be expanded in powers of v/c. When this done for the situation where the light source is approaching the observer with a velocity v along their 'sight-line' then the predictions of SRT differ from the classical theory only in terms of $(\mathrm{v}/c)^2$ or higher. Ives and Stilwell [224] demonstrated this effect using the radiation emitted by hydrogen atoms in a high-speed beam moving first towards the spectroscope and then away from it. Interesting, Ives personally did not agree with the SRT interpretation of this result that the electrons in the moving atoms are oscillating at a slower rate than those of stationary atoms. This is also the perspective adopted here. The SRT was analyzed extensively in paper IV of this series [225] and the Lorentz transformations were replaced on physical grounds with the temporal changes attributed to the longer times for electrons to synchronize back onto their mutual light-cones.

7.8 REINTERPRETING PLANCK RADIATION

Black-Body Electron Model

Planck's derivation of his blackbody formula was based on a "large number of resonators" filling the hot cavity. The nature of these resonators was never specified. UET views these as some of the electrons bound to the atoms on the inner surface of the cavity alternating in the exchange of 'heat' energy with the thermal lattice and then with remote 'radiation' electrons. BBR occurs when an electron in atom near the surface in the lattice of a heated solid alternates between exchanging energy with other electrons in the lattice and with remote (target) electrons far away from the lattice. Planck's oscillators are the mathematical representation of the atoms in the lattice, which are sharing their thermal energy with the whole, heated body. Any complex vibrational motion can be described by its Fourier transforms involving sine waves, which are always the result of simple harmonic motion. Thus, Planck's oscillators are simply a mathematical scheme without any physical analog in the dynamics of continuous radiation. This illustrates why Planck's scheme fails to explain why so little UV is emitted.

Surface Effects, not Empty Space

All calculations of blackbody radiation (BBR) effects focus on the 'hot' empty space (which is infinitely divisible) instead of the surrounding surface atoms on the inside of the enclosure. Kirchhoff focused on the cavity as the source of thermal radiation because the spectrum was seen to be independent of the type of material forming the walls of the cavity. The present theory explains this independence because this type of radiation is due to the interaction of remote ('cold') electrons with the ('hot') electrons associated with atoms in the inner surface of the heated cavity. These quasi-bound electrons alternate between remote interactions with the 'cold' electrons and other, local 'hot' electrons which are in thermal equilibrium with heated, solid body; i.e. this latter energy transfer only depends (on average) on the energy distribution within the heated solid body – that is, its temperature. In other words, the energy distribution measured in a remote detector is a reflection of the average energy distribution of the material, which thermodynamics views as similar as a source of energy when the material is in thermal equilibrium. The original Boltzmann energy distribution is now mediated by the requirement to pass some energy through the intermediate, surface electrons, which then radiate away to other 'far' electrons.

Planck & Boltzmann's Constants

The universal physical constants: Planck's h and Boltzmann's k, define the scaling or link between the microscopic (atomic) and the macroscopic world accessible to human measurements. Planck's constant is the measure of an individual electron's interaction with another electron; the universality of h implies the universality of the EM impulse. Boltzmann's constant describes the large-scale averages of these interactions at the aggregate level; i.e. for collections of electrons characterized by Avogadro's Number (approximately 10^{24}) and times involving comparable numbers of chronons (approximately 10^{-24}s).

7.9 REPLACING QUANTUM ELECTRODYNAMICS

Many modern physicists are prepared to accept that Maxwell's theory of electromagnetism is not appropriate at atomic levels but have transferred their loyalty to its so-called descendant: Quantum Electrodynamics (**QED**). Few seem aware that QED has continued to build on a physical fiction - namely, the æther even though today it is renamed the "EM field".

7.9.1 CONTRASTING UET WITH QED

Field Theories average away the Dynamics

Although field theories are formulated in terms of space and time parameters, there is no particular significance to any of the four sets of real numbers that supposedly describe a unique position in space at any time: all of the parameters get integrated away before the measurable quantities are finally calculated and these integrations are independent in each dimension. In contrast, the present theory is constructed upon the algebraic representation, called here **Natural Vectors** (or NVs). These mathematical 'objects' are explicitly 4D and each location vector $\mathbf{X}_j$ represents the **existence** of one *electron* (arbitrarily labeled by an integer signature, j) at a specific point in space $\underline{x}_j$ at a given time t_j. The relationships between these locations in space and time define the possible interactions between pairs of electrons, whenever they are 'on each other's light-cone'. Only the baseline for the temporal origin and spatial orientation in any reference frame is arbitrary (Galilean invariance). Temporal intervals are designated by an integral number of fundamental time units (*chronons*) while the spatial measures are scaled by the *luxon*, defined as the distance the electron moves <u>transversely</u> [226] in each unit of time ($\Lambda_0 = c\,\tau$).

QED quantizes the EM Potentials

All QED theories are based on quantizing scalar and vector potentials, which are then taken to interact with the 'free' electron. This is a mathematical technique directly resulting from eliminating the source electron. The only realistic view of the EM potentials are that they represent the **possible** response to the 'average' situation **IF** a <u>vanishingly small</u> electric particle were to be <u>imagined</u> to suddenly appear at that location in space at that instant of time; i.e. mathematics, not physics.

No Self-Interactions

In contrast with QED with its unphysical infinite self-energies, there are no 'self-interactions' in the present theory, as an electron can never interact with itself. This prohibition is generated both by the <u>finite</u> time between each *Send* and *Receive* point in the electron's interaction cycle and because interactions between pairs of electrons always occur as ray-like, point-to-point straight lines. No inertial electron can ever move along a trajectory that would take it from its *Send* location in time to reach its *Receive* location while both points remain on their common 'light-cone'. A similar analysis leads to the major conclusion that the vacuum is truly empty, as a pair of *virtual* electrons cannot be 'bent' back on themselves.

Interaction Saturation

In this and subsequent papers that explore the interactions involving three or more electrons, the “saturation hypothesis” has been proposed that limits, at any single interaction time, the interaction of any one electron to only one other electron. This choice of “saturated interaction” is a conscious rejection of the “superposition hypothesis” that has always been universally assumed in both mechanics and EM since Newton. Accordingly, if two electrons begin interacting together when electron #1’s local time is t_b and continues to interact exclusively with electron #2 until a later time (for electron #1) of t_a, when it either ceases to interact with electron #2 or switches its interaction ‘partner’ to another electron, then the duration of this interaction is referred to as their mutual “interaction-period” which is denoted by $\mathscr{T}_{ab} \equiv t_a - t_b$.

It is important to realize that while any two electrons are interacting continuously, no other electron can interact with either of these two electrons and so they are effectively unobservable to all other electrons in the universe during each interaction-period. However, since this research programme is based on a ‘realistic’ and not a ‘positivistic’ philosophy then it remains metaphysically consistent to view the two electrons as continuing to exist at all times. In contrast, the positivistic viewpoint would have us believe that even trees do not fall down in forests unless someone is watching or, at the very least, later finds them lying on the ground. The saturation hypothesis was used here to explain the phenomenon of interference between two or more possible optical paths. A later paper will further investigate this hypothesis and demonstrate that it provides a real and physical explanation of the mathematics of the quantum.

Momentum and hence energy are only conserved in the present theory across the completed interaction between the pair of interacting electrons; i.e. after the receiving electron completes its part of the transaction and has reacted to the exchange. These quantities are **not** conserved during the interaction, as they are exchangeable quantities that, following Newton, have no independent existence apart from the electrons that manifest these properties. In this regard they are like other variable properties of the electron, like velocity: no one has ever assumed that velocity has any independent existence, hence the necessity for inventing the concept of the ‘photon’ as the ‘carrier’ of these properties. Any attempt to measure (i.e. interfere with) either electron within the temporal interval of one single exchange event (one chronon) is excluded from this theory, which limits the exchange to the two committed electrons, according to the ‘saturation’ hypothesis. Any other attempt to measure the momentum of these electrons during their exchange will alter the situation and will lead to a different result. This is the ‘quantum’ view of this new interaction and will be explored in later papers.

Time Quantization keeps QED finite

As Schwinger, amongst others, has pointed out, the divergences (infinities) are traceable to virtual (intermediate) processes involving particles with ultra-relativistic energies. When this view is translated into the frequency domain, it means that very high frequencies (ultimately infinitely high) are the principal contributions to the infinities. In the present theory, the proposed quantization of the time between possible electron interactions eliminates all infinities that arise in continuum theories such as QED that integrate across space and time. There is never an interaction at zero separation between two electrons and there is always a finite number of interactions in any finite time interval – there are therefore no infinite frequencies or zero length wavelengths.

Too Many Interactions

Celestial mechanics suffers from being “too busy” in that even the three-body problem has remained not only insoluble but unstable (chaotic). The problem is that at every point in time, each of the bodies is interacting with all the other bodies. But QED is even worse, it is too busy in space as well as time since every point in space contributes virtual photons interacting even with a single electron; the resulting integrations generate mathematical infinities. QED suffers from the further major problem of being able to spontaneously create an electron-positron pair anywhere at any time. This is not a feature of the present theory; as electrons are viewed as eternal and only move forwards through time. A theory of the 'creation' of electron-positron pairs will be presented in a later paper that will provide an alternative model of the weak interaction.

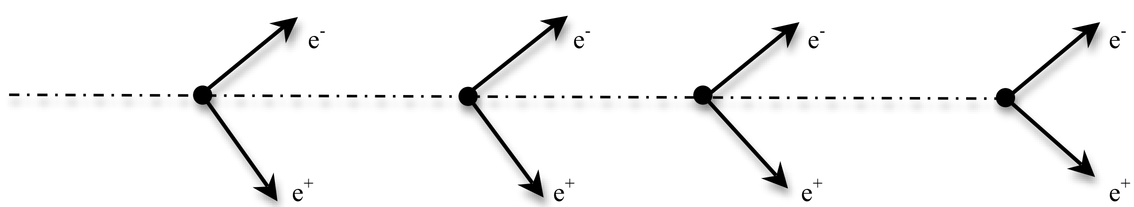


Fig. 17 Multiple Pair Production

7.9.2 INTERACTION DIAGRAMS

Real Feynman Diagrams

The present theory does make use of a new visual representation that has a superficial resemblance to Feynman Diagrams. However, now these ('Interaction') diagrams are explicitly viewed as illustrating what <u>might</u> actually happen in reality; in other words, these diagrams **always** represent possible **real** interactions between **real** particles. These diagrams are dramatically simpler than Feynman's diagrams that were actually one-to-one maps to abstract mathematical expressions.

No Electron Self-Interactions (Only Real Interactions)

All EM interactions in this theory are restricted to the 'light-cone'; in other words, this is equivalent to a photon always traveling at light-speed. Similarly, real electrons are limited to having interactions with other electrons that are traveling (relatively) at less than light-speed. Self-energy is a consequence of constructing a single-time (or Hamiltonian theory) where the mathematical expansion of a function is approximated by a convergent perturbation series where each term is viewed as a real example. This means that there are no interaction diagrams that correspond to the following, simple Feynman diagram of an electron self-interacting, (photons represented by dashed lines, as no wavy lines available in Word).

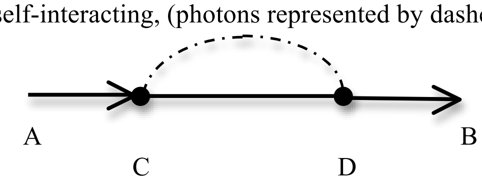


Fig. 18 Virtual Photon (Self-Interaction)

No Renormalized Virtual Photons

Since the photon is no longer viewed as an entity there can be no virtual photons (intermediate existents); i.e. the electron-electron interaction is quantized but there are no intermediate quasi-fluctuations leading to infinite divergences of the vacuum. The present theory rejects all so-called virtual particles as simply reifications of purely mathematical terms. The new theory does recognize that **no** electron can be isolated from all the others in the universe at any time. Some of these other electrons are observable and may be sought out in the experiments. However, many interactions with the target electrons remain unseen as they represent interactions with <u>remote</u> electrons that are outside of the bounds of the experimental region – either in the walls of the experimental enclosure or even further away, as the UET impulse is of infinite range (but with a diminishing chance of occurring). However, in UET the finite extent of the *chronon* means that over any finite experimental time period there is always a finite maximum (though very large number) of possible intermediate interactions with other electrons. The idea of 'virtual photons' is illustrated next, contrasting the Feynman view (a virtual photon emitted at B, goes to X and re-absorbed at C) with the Interaction view where such interactions are real but occur unobserved within the experimental region (except for time delays) but correspond to matched-interactions with pairs of electrons (E, F) outside the experimental region. Feynman does need these types of diagrams because they correspond to valid terms in his exponential expansion but have generated the common illusion that they are reality maps.

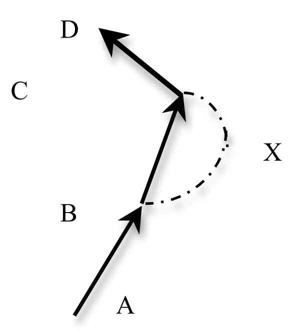


Fig. 19 a Feynman Diagram

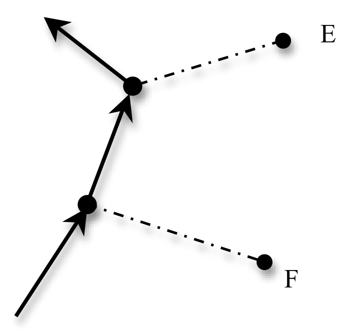


Fig. 20 Interaction Diagram

Action Minimization (No Complex Vertices)

The action-minimization principle resembles the policy of a cautious banker – don't make a new loan to a borrower until the first loan is paid back; in other word, "don't borrow too much from the future". In terms of interaction diagrams, this implies that two interaction lines do not cross between two electrons; equivalently, this means that the second interaction node (across time) must be the complement of the first interaction node. This is illustrated in the following diagram.

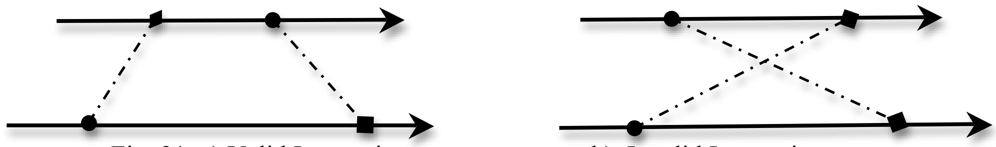


Fig. 21 a) Valid Interactions b) Invalid Interactions

No Backwards Travel

Feynman famously identified the **positron** with a negative electron moving **backwards** (relative to us) in time. This is not the model of a positive electron used here. This model was developed in the previous paper [227]; it proposes that positrons are real particles that have complementary interaction properties to negatively charged electrons. However, in both cases all electrons only move forwards in time, although both may participate in interactions with other electrons earlier in time. Examination of Feynman's derivations show that reverse-time 'paths' are really to capture certain time-ordered mathematical operations, not physical characteristics. This was a separate hypothesis to explain Dirac's anti-matter. This is another consequence of introducing "God'-time" into physics, where a single time is imagined spanning all of space.

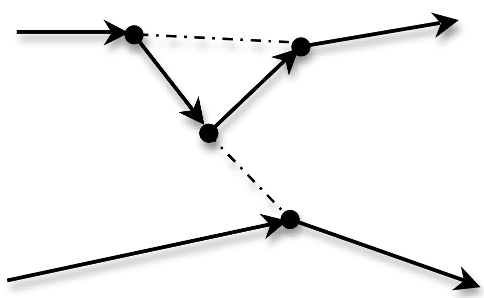


Fig. 22 Feynman Complex Vertex

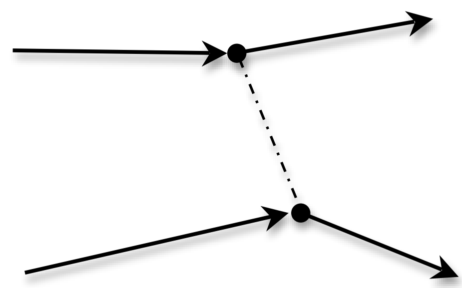


Fig. 23 Simple (universal) Interaction

No Pair Production

In order to accommodate Dirac's single-time model of the electron into his calculational scheme, Feynman introduced his reverse-time model of the positron so that a photon could mysteriously convert itself into an electron/positron pair. Again, this is the reification of mathematical terms and plays no part in the present theory. A later paper will present an alternative model of the so-called 'Weak' interaction that will provide a more plausible model of the neutrino interacting with nucleons.

Not a Corpuscular Revival

Although the present theory uses many straight lines, both in its calculations and in its diagrams, these lines do **not** represent the path of light **corpuscles**, which was the metaphysical alternative to the Wave Theory in the Nineteenth Century. This obsolete theory was supported by Richard Potter as late as 1859 when he was professor of Natural Philosophy and Astronomy at the University College of London University. As an optical-Newtonian, he believed [228] that: "*Light must be considered to consist of molecules emitted in sheets following each other at the distance of one wavelength; the sheets being perpendicular to the rays in ordinary media. These molecules must also have axial and equatorial directions*." As we have stated here several times, the present theory does **not** view light as an entity, either wave or particle, but as a series of complex interactions between serial pairs of electrons.

7.9.3 ELECTRONS vs. PHOTONS

EM & Electron Interactions

All theories of particle dynamics, including the Standard Theory, begin with the concept of the 'free' particle and then 'turn on' the interaction slowly between them are missing the very essence of the idea of particles: interaction and existence are synonymous. Even QED 'turns on' the EM interaction between a pair of 'free' electrons, asymptotically and adiabatically.

Radiation-Gas vs. Electron Model

Einstein's concept of the photon as a particulate form of EM energy originated with his awareness of the mathematical similarities of the entropy formula for BBR and an ideal gas. However, unlike the myriad elastic collisions of ideal gas molecules, photons do not interact with each other – only with the remote emitting and absorbing electrons.

Einstein wrong, Planck right about EM

Planck got it right in his approach to EM – this is an **interaction** that is quantized. Einstein fell into the ancient fallacy of confusing the map and the territory, known as "reification", where the symbols (or words) are promoted to the ontological peak of existence – he visualized the photon as a real particle, with its own independent existence (an entity). Since light is **not** a traveling entity, it would always be impossible for anyone "to catch up with it", as Einstein imagined in his famous 'thought-experiment'. Relationships do not have the same independent properties (as sources of interaction) as entities – it is always impossible to 'weigh' a marriage but never a bride. Sharper conceptual categories lead to clearer thinking.

7.9.4 EXPLAINING THE PHOTON

The Photoelectric Effect

The quintessential experiment that required the concept of a photon was the photoelectric effect, as Einstein first recognized.

In the UET model of the photoelectric effect, high-energy electrons in the 'hot' EM source exchange some of this energy with the low-energy electrons in the 'cool' target metal, which then exceed the binding energy interactions in the metal. An explanation of this effect and the scattering of light by electrons (the Compton effect) will be deferred to the next paper when the focus shifts to the principal entity of this theory: - the electron.

A Photon is not an Elementary Particle

According to the current *Standard Model*, the micro-world consists of fermions and bosons. This is a mathematical scheme to preserve the statistical characteristics of the (wave) functions used to characterize real particles (e.g. electrons) and their interactions (e.g. photons). The UET adopts an ***ontological*** perspective that places existence at the foundation of its scheme. Real particles that are truly atomic (i.e. not composites) are designated as ***entities*** because each example **exists** in the world unconditionally: only electrons are given this status in the Universal Electron Theory (UET). The foundational property of such entities is that they must interact with each other (otherwise their existence would remain indeterminable). Thus, the next ontological category is that of ***relationships*** between entities, such relationships are contingent: they may occur some times but not always and depend on the ongoing existence in time of their associated entities ('no bride, no marriage'). UET only posits one type of interaction between electrons called (for historical reasons) the electromagnetic (EM) interaction. The occurrence of this interaction is manifest between two electrons as an exchange of momentum at two distinct times, at each electron, that is observed as an instantaneous change in velocity of each electron as it participates in each interaction. It is the exclusive occurrence of one or more serial interactions between two electrons that is referred to in UET as a photon. Each interaction event is modeled here mathematically as an impulse that exchanges one half unit of kinetic action that has the magnitude of Planck's quantum of action, designated by the symbol h. Thus, the mysterious concept of '***spin***' is linked to the ability to exchange action; this is why the photon was assigned a unit value of 'spin' (from the two related impulses).

The Unit Interaction is not a Photon

The inter-electron **interaction** at the heart of UET cannot be separated from the particular sending and receiving pair of electrons. Therefore, the interaction concept does not correspond to the idea of a photon that is emitted from one electron and travels across the universe until it happens to hit an electron where it is absorbed. In the photon model, another electron could happen to intercept the photon and the original interaction would not occur: this element of randomness is rejected in UET, where an interaction agreement is established between the two electrons and remains in place until the receiving event has occurred. If other interactions occur involving third-party electrons with the later-electron prior to the completion of the principal interaction then they must leave the later-electron in exactly the same state as if they had not occurred; i.e. the electron must be at the same location in space at the later interaction time and moving with the same velocity. Similarly, for advanced interactions, the earlier state must still prevail (where the 'send' electron is already at a later time than the earlier 'receive' electron). This explains why a 'photon' cannot be intercepted "emerging" from one of the Young slits, without "destroying" the possible interaction with the electron in the target screen. This experiment is an example of multiple electron interactions involving the source electron, many electrons in the slit-screen and many electrons in the target screen.
When a source electron decides to commit to an optical path that leads to an electron in the screen then it 'knows' where all the other possible electrons are while making this decision. Any attempt at a measurement will introduce extra electrons that will change the decision-making process at the source electron.

Unlike localized (one-time) mathematical models of EM, the UET electron 'knows' the reaction strength **and** direction of each interaction once it has identified which remote electron (negative or positive) with which it will interact. It is only the choice of electrons in the interaction-pair that appears to be probabilistic (because of the vast number of possibilities), all subsequent activity is fully defined. This does not mean that UET implies a determinable universe, only direct causality.

When interacting with a remote electron via a 'photon' of frequency (1/N), an electron does not exchange a single quantum of energy (h/N) at one instant of time but exchanges N impulses, each of energy ε_0 (½ m b^2), in series (see §6.4.1). The UET model explains why a photon does not spontaneously divide into two 'daughter' photons each with half the energy (and frequency) but moving apart in divergent transverse directions. This possibility is not excluded by the conventional photon model but no explanation is offered why this is never observed (see *Too Many Interactions* above).

Instead of geometrizing empty space at a universal single moment of time, the remote EM interaction (i.e. 'light') is about synchronizing the interaction between sets of pairs of electrons, each pair at two points in space at two moments of time. Once again, the attempt to replace a dynamic view of the universe with a simple, static model that we can 'photograph' in our imaginations has failed; it is **dynamic time that defines reality**, not sterile space or simple imaginative models.

It has long been known that light itself cannot be observed and this is still true for single photons; only <u>effects</u> can be seen. Yet scientists still wish to posit a "carrier of energy" between electrons and construct illogical paradoxes, such as to ask: which slit does a photon go through in Young's experiment. It is existence in time that implies locality; no locality means no existence. We do not need to invent hypothetical objects in nature to preserve our mathematical theories.

Electrons/Gold vs. Photons/Wealth Analogy

A person's wealth is an abstraction – the dynamic set of relationships between the real person and the set of real assets that the person owns at any time. In contrast, real money (like gold coins but not paper cash) is a real asset that moves from person to person and has its own independent existence. Similarly, energy is like wealth, it is an abstraction; it is not an entity with independent existence in its own right (like coins) but a relationship between real objects involving their relative velocities. So, photons, as the "carriers of energy" <u>do not exist</u>, they were introduced as a book-keeping entry to preserve the so-called conservation of energy [229]: they are just not examples of reality. There is a meaningful question about electrons shot at a double-slit but the realistic answer to this question will have to await the next paper.

8. SUMMARY & CONCLUSIONS

In this final section, the results and conclusions from this paper will be briefly summarized in order to draw out the major implications from the material. The paper ends with summaries of the future papers in this programme. To repeat what Dirac said [230] on his quantum scheme: "*The justification for the whole scheme depends on the agreement of the final results with experiment*."

8.1 OBJECTIVES

Ever since Newton, as an eminent mathematical physicist recently wrote: "*calculus has been absolutely essential for a proper understanding of physics!*" This reflects the great simplicity of Newton's mathematical approach to representing reality: the focus has always been on the single-point in space at any time: the technique of differentiation now simplified changes in the world to **local** relative changes in structure or behavior in the tiniest neighborhoods of each target point. The digital asynchronous interaction between point-like electric charges now means that this viewpoint is far too narrow, its retention has required the equal retention of continuous properties (fields) of the empty spaces in between – the resulting mathematical **infinities** have become an embarrassment that can no longer be tolerated. This has been the motivation here for constructing a model of physics built around finite forms of mathematics – matrices and difference calculus. These were introduced in a new integrated form in the last part of section 8.3 of paper V in the mathematics of Discrete Natural Vectors.

The implicit 'star' of this paper is actually James Clerk **Maxwell**, today viewed as one of the greatest physicists of the 19th Century. This 'giant of science' has been the focus of much of the background research in this programme. However, there is an unknown side to the famous EM equations that are Maxwell's principal legacy today. The consensus in physics today is that these equations provide a **solid** foundation for understanding the classical (i.e. wave) properties of light. Classical electromagnetism (CEM) is a modern artifact, constructed from Maxwell's mathematics, Helmholtz's 'electric fluid' and widely believed to have been confirmed by Hertz's remote induction experiments. The history of science shows that it was the belief in the luminiferous æther that was in fact the inspiration for Maxwell's evolution of his EM ideas and [231] he totally rejected the substance model of electricity. Furthermore, lurking implicitly behind all of these conceptual components is the ancient "Continuum Hypothesis" that assumes that both the electrical substance and the interactions between contiguous, infinitesimal cells containing this substance will act continuously across all time and space. The discrete reality of the electron is a stark challenge to these smooth assumptions. A study of 19th Century physics [232] also shows that almost all the major proponents of this view of EM were deeply religious men, who were motivated purely on religious grounds alone to reject the Newtonian action-at-a-distance model between material points interacting across the void. The notion that there were parts of the world were nothing existed was anathema to these devout men who believed that the Christian god was imminent – that is, present everywhere throughout space and time. As a result, physics has taken only one of the roads available for explaining optical phenomena – this paper offers another route forward.

This paper once again firmly builds on the **history** of physics, having found that this long view of physics has exposed many unstated assumptions and has exposed the critical points where purely mathematical innovations were smuggled into physics because they could provide an arithmetical agreement with some experimental results but failed to provide any new physical understanding. In his popular exposition of '*The Strange Theory of light and Matter*' Feynman unapologetically outlined the "physicist's history of physics" (the myth-story that physics teachers tell their students) while admitting [233] it is never correct and not necessarily related to the actual historical developments, which he freely admitted he did "*not really know*". Feynman had a great intuition but this lack of knowledge of the history of physics and its philosophy were his two greatest weaknesses. Since Feynman's theory of QED is a purely mathematical theory, he was forced to view light [234] as a real object that interacts with real electrons. Like almost all theoretical physicists since 1925, Feynman did not question the modern theory of quantum mechanics (but he did reformulate it in a very productive manner). So he ended up with this "*jewel of physics – our proudest possession*" while admitting that not only his graduate students don't understand QED but writing that even he doesn't understand it, even going so far [235] as to state "*nobody understands why Nature works this way*." This programme rejects the idea that the goal of theoretical physics is simply to create mathematical techniques that produce numerical agreements with experimental results. Such numerical agreements are useful but **insufficient**. Without physical understanding, there is no real progress in physics – only hollow self-congratulations; "*don't ask, just calculate*" is a pathetic excuse for mathematicians but it is not the way physics has shone its light upon the world. When natural philosophers can present an image of the world then, not only physics benefits, so does everyone because we all share this powerful faculty of visualization – it's non-linear relationships become immediately obvious and inspire new acts of the imagination, providing solid stepping stones for the progress of science.

8.2 OPTICAL EFFECTS

Section II set the stage for the rest of the paper as it reviewed the historical context of the two major ideas that are the focus here, namely: the concept of light-waves and the earlier notion of corpuscles of light. Although writing a modern paper on optics might seem quaint today, it is usually forgotten that the ideas of optics, especially the deep metaphysical assumptions concerning the nature of light, underlie much of modern physics, while they are rarely discussed in the one semester course that is all that most physicists receive today.

This section emphasizes the central role that Maxwell's ætherist theory of electromagnetism (EM) has played in the last 150 years of physics, not least in providing a theoretical framework for explaining optical phenomena. The foundations of this theory are shown here to be deeply flawed and do **not** form a firm foundation for extrapolating its macroscopic summary of experimental findings down to the micro-sphere that is the domain of physical optics. Any theory of light must focus on the actual processes that are occurring in various optical situations, including transmission and reflection but most importantly those that are happening in the various <u>sources</u> of light. These phenomena are described here, as they will be revisited many times throughout this paper. **Synthesis** (bottom-to-top) is the highest form of understanding; analysis is deficient.

8.3 CLASSICAL THEORIES OF LIGHT

Since the thrust of the present paper is to present a new theory of light, it is important to remind the reader of the earlier, classical theories of light that dominated the 19th Century obsession with this major area of experience. The opportunity is also taken here to recall some of the long existing problems with these theories that have little to do with quantum effects.

8.3.1 PROBLEMS

Maxwell rejects Gauss; Hertz gets himself confused

One of the greatest tragedies in the history of physics was Maxwell's rejection (on theological grounds) of Carl **Gauss**'s revolutionary idea of asynchronous EM action. As Maxwell wrote [236] in the final paragraph of his famous *Treatise*: "*I am <u>unable to conceive</u> of a propagation in time, except as flight of a material object through space or as the propagation of a condition of stress in a medium <æther> already existing throughout space*." Thus was physics <u>unprepared</u> for the discovery of the <u>particulate</u> electron 25 years later. Physicists are still betting on the <u>continuum</u> foundations of reality when they believe that differential equations map directly back to reality. The present theory calls their bet. Modern historians of science have now done an excellent job of reviewing the evolution of EM thought in the 19th Century. Recent research contradicts the oft-repeated error that Hertz confirmed the Maxwellian prediction of EM wave generation. Unfortunately, too many academic physicists are still obsessed with adding some small innovation to the latest theories and fail to alert themselves to these important new insights into their own science that has been built on very weak foundations.

8.4 QUANTUM OPTICS & PHOTONS

It is often said that as long as one is dealing with situations involving the interaction of light with light, such as occurs in interference and diffraction, the classical electromagnetic theory (or any wave theory) seems to give a complete account of the observations. Problems arose when interactions between light and matter are considered, especially in the emission and absorption of light and in the movement of light 'through' matter (dispersion). In these latter situations, the classical wave calculations predict results widely divergent with the facts. The most conspicuous anomalies arose with Black Body radiation and the photoelectric effect that should never occur with low intensity light. It has also been pointed out that we never see light itself but only the effects it produces; neither an individual wave or light-quantum are ever observed. None the less, mathematicians have convinced themselves that their analysis of interference and diffraction is so accurate that they have no doubt that light has a wave character. This conviction has been carried over into quantum mechanics, especially when experiments 'seemed' to show that atomic scale material particles also exhibited wave-like features. Although claims are often made that light and electrons are so far away from everyday experience this does not stop humans importing their macroscopic experience into their imagined realms of the atomic world. We still wish to interpret the world in terms of miniature billiard balls or water waves crossing empty space.

This section opens with a review and critical analysis of the experiments that lead to Einstein inventing his concept of the light-quantum that was soon renamed the *photon*. Historical analysis is applied again to dismiss contemporary misconceptions of Black Body radiation, the photoelectric effect and the stimulated emission of radiation.

8.4.1 PROBLEMS WITH RADIATION

A key point made here was the mis-focused attention in Black Body radiation on the enclosed cavity instead of the reality of the hot surface of the surrounding material body. Again, historical research shows how Planck stumbled towards his theory and how he was forced to "guess" major steps to devise the most important equation in modern physics: $\varepsilon = h\, f$. The photon model was examined in this section and also found wanting. Einstein over-extended the mathematical similarities of an ideal gas of non-interacting particles with the existential appearance of real interactions that characterize all EM activity. The foundational ideas behind stimulated emission were also examined here and the critical idea of phase was found to be missing.

8.5 LIGHT & QUANTUM ELECTRODYNAMICS

Physics as Phenomenology

This section traced the wave/particle 'paradox' to the rise of **phenomenology**, where an equation was considered a sufficient explanation for a macroscopic observation. The problem arises when such equations introduce symbols that have no such mapping to large-scale reality or any corresponding experimental procedure. This leaves us, in the case of light, where Max Planck writes: "*the position is an exceedingly unsatisfactory one. We have two theories facing each other like two equally powerful rivals. It is probably correct to say that neither theory will prove completely victorious*." [237] This is not a problem where two different mathematical schemes are used to describe different experiments but becomes a major problem in philosophy when the terms in these schemes are given a contradictory ontological interpretation: reality does **not** oscillate between two wildly different manifestations. This failure is assigned to a political compromise between 19th Century rivals.

8.5.1 QUANTUM ELECTRODYNAMICS

This section summarized the evolution of the mathematics that was developed to describe the interaction between light and matter, culminating in Feynman's version of quantum electrodynamics (QED). All of this activity, centered on sophisticated mathematics, was incapable of providing a single conceptual interpretation that could be agreed to by all physicists.

8.5.2 FEYNMAN'S ELECTRODYNAMICS

This section reviewed the development of Feynman's ideas about electrons and their interactions. It showed how Feynman betrayed his original physical intuition that electrons did **not** interact with themselves (a view upheld here) by developing a quantized field theory. Like all his rivals, Feynman never challenged the idea that Maxwell's Equations had any validity at the level of electrons, since fields were defined to have real values at every point across space and time.

8.5.3 RE-INTERPRETING QED

Mathematicians from Pythagoras and Euclid to Einstein and String Theorists have always obsessed over empty space and its representation in the abstract rules of **geometry**. In contrast, the present programme focuses on real **matter** – those rare points in empty space occupied by the fundamental existents of the world – **electrons**: space now reverts to its passive Newtonian role of separating electrons at the same time. Light is not considered an existent, manifesting an independent existence as it travels from one empty point in space to another across time. It is viewed simply as an indication that an **interaction** has occurred between pairs of electrons over a finite interval of time, characterized by the identity of the two electrons involved and their space and time parameters (actually differences) at the two times defining each interaction.

The quantization of time (implied by the *chronon* cycle time) automatically eliminates the infinities in Quantum Electro-Dynamics (QED) by introducing a natural lower limit in the spatial separation, defined here as the distance generated by multiplying the 'speed of light' parameter c by the *chronon* τ and called the ***luxon*** Λ, so: $\Lambda = c * \tau$. This converts the traditional integrations in QED from zero spatial separation out to infinity into finite sums of discrete quantities. It was at the 1938 Solvay Conference that Heisenberg suggested that the difficulties encountered in QFT "*will have to be sought by ascribing a finite value to a new constant of nature that has the dimension of length*." Heisenberg did not name this new fundamental constant (called here the *luxon*) but he did identify it with the classical electron radius Λ_0. He saw this as a sort of limit below which the concept of length loses its significance. In the present theory, this is the minimum quantum of distance below which **no** interaction can occur because of the discontinuous and periodic nature of the EM interaction posited in the present theory and characterized by the time quantum or *chronon* τ. As Schweber astutely recognized, this would imply that the possibility of the continuous time displacement of the state vector (or wave function), described by the Schrödinger equation, must [238] be abandoned.

Feynman Diagrams reified like Ptolemy

Mathematicians have frequently fallen into the **reification** trap assigning reality to the symbols used in their calculations. It is likely that the followers of Ptolemy (but possibly not Ptolemy himself) simply assumed that the epicycles were actually representations of the planetary trajectories involved, rather than realizing that this was an early attempt at calculating key periodicities (using finite Fourier transforms). Feynman diagrams are the latest calculational technique to be misinterpreted with each term in the exponential expansion of the action integral being now given a reality in terms of virtual photons and virtual electrons. Even Dyson first fell into this trap, when in 1949 he claimed [239] that: "*the graph corresponding to a particular matrix element is regarded, not merely as an aid to calculation, but as picture of the physical process which gives rise to that matrix element*." Dyson soon realized this was a mistake and later never referred to this interpretation of the diagrams.

QED is a Quasi-Statistical Theory

QED, like CEM upon which it is built, is a quasi-statistical theory that implicitly eliminates the source of electric interactions by introducing fictitious, mathematical functions (the scalar and vector **potentials**) that 'act' upon the single target electron at the 'field point'. Like all field theories, these functions have to be integrated away across all of space.

8.5.4 PROBLEMS WITH QED

Feynman was very clear that QED studied the interactions between two **real** entities – light and electrons. Unfortunately, although he acknowledged that both 'objects' exhibited particulate (localized) and wave-like (periodic) properties he still chose to refer to both as 'particles' (that could be described by lines or 'tracks' moving through space). The greatest weakness of Feynman's approach is that it is still only a phenomenological model – a powerful mathematical technique that provides no understanding. Indeed, his theory fails to advance our understanding beyond the rock that sank Newton's 'ship of light' – namely, a mechanism for explaining such basic phenomena as the partial reflection of light by glass, admitting that this theory provides "*no satisfactory mechanism to describe even the simplest of optical phenomena*".

8.6 REMOTE ELECTRON INTERACTIONS

Over any finite time period (greater than 10^{-18} seconds), a particular electron may interact with just one other electron (through several consecutive interactions) or it may interact with several (even very many) other electrons in a correlated periodic manner. It is the erroneous reification of these two distinct modes of interaction into one real entity, called light, that has led to the magical view that 'light' can be both a particle and a wave, even though these are logically **opposite** (not 'complementary') concepts. They are alternate mathematical techniques to be applied in different situations but **reality** does not alternate between two radically different manifestations, just because we call them "complementary".

Chapter VI elaborated on the idea of remote, asynchronous interactions between electrons. It began with a reiteration of the principal ontological properties of this electron model. It describes how certain mathematical creations (potentials) were introduced in the classical studies of electromagnetism to simplify the mathematical manipulations but were without any experimental justification. The emphasis here is on the key semantic category of **relationships** that focuses on interactions between two (otherwise) independent existents or **entities**, which have always been the focus of earlier studies of nature. The abolition of continuous interactions returns attention to Newton's original conceptual innovation: the **impulse**. The other challenge to conventionality is the abolition of the assumption of arithmetic addition of forces; instead, the key idea of **saturation** is proposed that ensures that any single interaction never involves more than one other remote electron.

The majority of this chapter (§6.2.5) was dedicated to finding an analytic solution to the problem of two-electron scattering that respects the full, asynchronous interaction between them. This is a problem that has resisted **all** earlier attempts, using either Maxwell's theory or quantized versions (QED).

An earlier paper in this series demonstrated that a continuous model of interactions is not possible when instantaneous interactions are replaced by interactions involving finite delays that can only occur when the inertial point particles must be on each other's 'interaction cone'. Field theories bypass this constraint by using 'mass-less' fields involving one global time. It is not sufficient to introduce a finite propagation time into a system to generate complexity, for each system component needs a 'natural' cycle time. This quantization of temporal duration allows the effect of arrival time on phenomena (i.e. the **phase** of the interaction) to become significant. Without this new opportunity to co-ordinate their actions together, it is very difficult to imagine how any system could achieve complexity or stability. For electrons, this ability to synchronize their activity determines which electrons will interact together. It is the observed stability of Nature that suggests the electron's interaction period is **cyclic** and not random; the **3-body** problem defeats continuous interactions.

8.6.1 TWO-ELECTRON DYNAMICS

Although this model analyzes the interaction <u>at</u> each electron in terms of an equivalent impulse, it is important not to think of these two impulses as independent or real – they are **not** created at each electron and '<u>launched</u>' across space with their own <u>independent</u> existence that happen to 'collide' somewhere between them. These two impulses are integral components of this **single** relationship: the electron interaction occurring between one pair of electrons at unique times for each electron. When a single interaction occurs between two electrons the identity of each electron has already been established – this is the heart of the present **selection** mechanism and contrasts completely with the anonymous '**broadcast**' mechanism of QFT.

Often, when two remote electrons have decided that they form an optimum pair to exchange a unit of momentum it is very common that these two will again form the next optimum pair. This exchange can be repeated for very many consecutive interactions, characterized by a large but finite number. It is this <u>interaction set</u> between a pair of remote electrons that is now viewed here as the reality lying behind Einstein's mysterious concept of the 'quantum of light' or ***photon***.

This section explored in detail, the dynamics of two isolated electrons that repeatedly experience only the 'far' transverse interaction. It demonstrates that each electron undergoes an oscillating motion between two extreme biconal vectors.

8.6.2 THREE-ELECTRON DYNAMICS

This section extended the detailed 2D solution to the full 3D scattering model using parabolic trajectories in each of the two transverse directions, with the electrons crossing the z-axis at the same moment in both directions.

8.6.3 MANY-ELECTRON DYNAMICS

This theory is fundamentally about interactions and information. Each time an electron participates in an interaction, it needs to know *the when and the where* of its partner in this transaction making this is an inherently ***non-local*** theory. It is possible that the total action of all electrons is minimized over an extended time-scale. Momentum is always conserved across each **complete** interaction but **not** at all times in between (contrary to the Helmholtz continuous energy *hypothesis*). Energy is only conserved in individual attractive interactions or across several, consecutive and completed interactions.

The introduction of <u>interaction-selection at the level of pairs of electrons</u> introduces the concept of *information* explicitly into the foundations of physics. At each interaction point, in every electron's chronon cycle, the electron must determine which other electron in the universe will be selected for participating in a possible interaction. This has never been a problem when physics simplified the world by making interactions continuous at *all* times and universal between *all* other electrons.

Section 6.3.2 presented a detailed mechanism for how two electrons decide if they will exchange momentum at their next interaction times. This showed that the basic idea of a two-phase, cyclic interaction (previously used to define when real momentum is exchanged) can be extended to the idea of exchange of necessary information on each partner's place in space and time, its direction of interaction in space (i.e. charge) and the direction of interaction in time (retarded or advanced). So, in this new model an electron decides on its next partner (**selection** or information phase) and then a momentum changing impulse is exchanged (**action** phase).

8.6.4 KEY ROLE OF THE SOURCE

This section developed a generic model of optical **sources** that can be applied in all situations so that attention may then be refocused on other parts of the optical system. The near universal characteristic for a 'source' electron is that it undergoes periodic displacements across a small region of space. This requires the presence of one (or more) nearby 'driver' electrons that are interacting locally with the source electron to generate this local activity. In order for this activity to become an optical source, there must be a remote 'target' electron that must interact several times with the source electron over several local cycles. This scheme indicates that '**far**' radiation phenomena are examples of **three-electron** systems.

This section also developed a microscopic model that showed that <u>Bohr's energy-frequency hypothesis</u> is actually a generic rule for all source transitions between electron states (both atomic and electrical), as Fermi suspected.

8.7 LIGHT AS REMOTE ELECTRON INTERACTIONS

Section VII returned to the experimental phenomena that were introduced in section II and were there explained by classical optical theories in section III. Here these experiments are re-interpreted in terms of the theory developed in section VI.

8.7.1 THE 'NATURE' OF LIGHT

All earlier models of light, when they consider its physical basis, have conceptualized the interaction as an **object** (wave or particle) that is **created** from a separate kind of objects (the 'emitters'). This decision reflects that both words are nouns (although with vastly different metaphysical implications) and the ancient philosophical approach to construct the world from fundamental substances ("fire, water, etc."). As an object, light must then exist as an independent entity moving away from the emitters carrying with it energy and momentum until it collides with another set of objects (the 'absorbers') when it ceases to exist. In contrast, UET rejects this approach and proposes that reality is **only** constructed from electrons that alter each others motion via a single interaction between a pair of electrons separated in space without introducing any additional, intermediate '**carrier**'.

Similarities and differences between the present EM theory and Wheeler and Feynman's action-at-a-distance theory are listed here to demonstrate that some of the concepts in the present theory have previously appeared with a sterling pedigree.

8.7.2 THE 'PATH' OF LIGHT

Even though the present theory rejects the idea that 'light' is an entity that travels through space, it is still possible to talk about the 'path of light'; but now this is a **logical** concept constructed from the sequence of locations where a single interaction activates a series of electrons as these electrons pass along the energy and momentum 'disturbance'. In the UET model, since light is not viewed as an entity, it can only interpret rays as a mathematical representation of the direct, **geometric** lines linking electron-electron interactions along the optical path and, like rays, the finite number of interactions, from source to final absorber, can be counted over any finite time. Remote electrons interact either directly (along their complete, line-of-sight, relative centers) or indirectly, via one or more intermediate electrons that are 'temporally near' the direct 'ray'. In other words, any action-at-a-distance model is explicitly **not** a 'moving particulate' model, nor is it a 'traveling wave' model. Also, unlike **Huygens**, there are **no** new spherical wave-fronts originating along the way. In summary, Feynman's theory of light (QED) is about hypothetical *photons* moving **everywhere** through space at **all** times while this theory is about hypothetical interactions occurring and propagating only between real electrons at finite times.

8.7.3 REFRACTION & DIFFRACTION

All refraction and diffraction effects in wave theories of light are seen as being due to combining the influences from the direct and secondary interactions. Real optical scattering involves many electrons in myriads of atoms re-interacting with electrons in other atoms in a vast many-body complex. The phenomenon of refraction critically depends on how fast the EM disturbance propagates through a real material medium from electron to electron. A detailed model is described in §7.3.4.

The value of the universal constant c (3×10^{10} cm/sec) is **not** viewed, in this theory, as the 'speed of light moving through a vacuum' or the limiting speed of material objects but the **metric** linking the spatial separation of electrons (Δx) to the temporal separation (Δt) when they are participating in a single EM interaction; i.e. $c = \Delta x / \Delta t$.

Water and sound waves **do** follow Huygens Principle because there is a material medium for the waves to carry energy and momentum but the luminiferous æther has never been found, so the wave theory of light is an extrapolation of macroscopic waves in real material media to a microscopic reality, without any medium. The one common factor is that the mathematics of waves does not care about the physics of the situation (a medium) but only the size of the wavelength when compared to the width of the slit (or gap); i.e. this is a geometric extrapolation: mathematics once again, not physics.

It is well known that detecting appreciable interference requires that the two-slit separation should be about equal to the wavelength; in other words, the difference in optical paths must be about the same size as the wavelength. Alternatively, it is proposed here that the difference in the travel times between two interfering optical paths is about one complete cycle of the source emitter, even when secondary emission occurs from real electrons near the optical paths. Section 7.4.2 provides a discrete model of destructive and constructive **interference** without introducing wave-like carriers of energy. A detailed model is also included here of the phenomenon of optical interference near a straight edge.

8.7.4 INTERFERENCE

Interference implies Periodicity

Hamilton's "principal function" was another mathematical scheme to describe the physics of interactions at several locations across space, in terms of **simultaneous** action; i.e. calculated all at the same time. The experimental results always look for interference effects at minimum and maximum nodes at points in space. This approach only provides evidence that a real phenomenon is occurring that exhibits the periodic addition and subtraction of interactions at critical points in space; wave theory is only one mathematical scheme that can represent this class of interactions. The present theory offers an alternative. The problem with using such a technique (as is done in most field theories) is that at any one instant of time, most locations are demonstrating the effects produced by much earlier times when propagation times are finite.

Fresnel's Two-Mirror Interference Model

One of the crucial experiments that saw the victory of the wave theorists in France was the production of interference using two mirrors by **Fresnel** that avoided any nearby material to influence the passing rays, as had been proposed as the mechanism for interference by the 'emissionists'. The model used here uses much of the mathematical thinking of the ray theorists (i.e. Pythagoras theorem) and is sufficient to provide an explanation without introducing any wave mathematics or wave-like thinking. Time differences across alternative pathways in this theory are sufficient to explain the observed effects.

This section provides an extensive summary of Fresnel's theory of **diffraction** (usually long forgotten) and contrasts it with the UET theory of diffraction as the phenomenon of diffraction has been long regarded as the key evidence for the wave theory of light. The present theory gives the electrons in the material surrounding the holes (or slits) a new, central role in providing a causal explanation for diffraction and interference. Incidentally, this 'hole' theory does **not** invoke virtual electrons in the "Dirac Sea" as making any real contribution. These holes here are the ***absence*** of real matter, leaving nearby matter without any complementary 'subtraction' of possibilities. In this model, a specific response on the target screen does reflect the fact that only one (of the two) optical paths in the Young's slit experiment was taken but the existence of the other slit (or hole) is still significant to the decision processes that can be traced back to the originating, source electrons.

8.7.5 UET RADIATION MODEL

Since the present theory dismisses Maxwell's æther model of electromagnetism as a valid explanation for Hertz's famous experiments, it behooves us to present an alternative model of EM radiation. This was described in section 7.5. UET is consistent with Classical EM (CEM) theory since electrons are viewed here as always moving at constant velocity, **except** at interaction points, so that 'radiation' only occurs when the electron instantaneously changes its velocity. The 'radiation' is **ray-like** and limited to a line-of-sight exchange of momentum between the two electrons involved. Only when large numbers of interactions are involved will they appear to be spread in all directions (isotropic). In the limit of large numbers of interactions in a limited region of space and time, the present theory will approach the continuum limits of CEM. This chapter includes alternate models of Black Body radiation; focusing on the hot cavity walls, not the empty space in between.

8.7.6 POLARIZATION

The key to understanding polarization is to consider ordinary light as always consisting of mixtures of transverse activity that are separated by various physical interventions. In particular, polarization becomes manifest only after light has had an opportunity to undergo such an interaction with real matter, which then leaves the polarized fractions distinct. Polarization is now viewed as induced oscillations (in the transverse plane) combined with finite delays at each atom for absorbing and retransmitting the excitation between electrons. Secondary electrons are constrained to move only in certain 2D directions and this distortion remains in the "light ray" thereafter. The only real effects in Maxwell's theory in material media occur where the electric vector is experienced by electrons in the atoms of the medium so that the only actual difference in these two theories is between the finite impulse (UET) and the continuous electric force vector (Maxwell) but this is too brief to be detected in most experiments.

Similarly to Lorentz, the present theory explains EM optical activity as the remote impact on the electrons in the source and in the intermediate matter in the optical path as the mechanism for the observed effects.

Since the electron is viewed here as the foundational entity of all matter it makes the prediction that *h* and the fine structure constant α will appear everywhere throughout microscopic physics, irrespective of which 'fundamental' force is involved.

8.7.7 REPLACING QED

Not only does the present theory reject the use of Maxwell's EM theory at the scale of electrons (an unjustified hypothesis) but it also rejects all field theories that focus on empty space, whether these myriad "points of nothingness" are claimed to experience an EM field or not. It is only when special points in space are occupied by an electron is it possible to determine if there is any interaction occurring there at an instant of time. The UET is constructed on such physical concepts at the atomic scale, not abstract mathematical schemes that resist physical interpretations.

It will have been obvious to those who have read this paper closely that UET bears a strong debt to the ideas found in Feynman's theory of quantum electrodynamics (QED). It is believed here that this is so because Feynman exhibited a very strong physical and visual intuition in his approach to physics. This was exhibited by the rapid adoption of his eponymous diagrams; unfortunately, the mathematical evolution of these are often forgotten and today, too often, they are given a direct physical interpretation - once again demonstrating the mathematicians' rush to **reification**. The present theory was also deliberately developed to promote visual thinking about this domain of existence, encouraging physicists to develop similar macroscopic metaphors at the microscopic level. It rejects the pessimistic view that this world cannot be reached by our own imagination. We caution that the importation of our existing abstractions, such as perfect billiard balls or waves in perfect fluids, may well be too simplistic but suitable extensions (as suggested here for point particles) may well prove productive. Section 7.9 included some early suggestions for a pictorial scheme that bears some resemblance to Feynman diagrams but the corresponding mathematics is vastly simpler. The moral here is that the story (concepts) come first before the mathematics is introduced to calculate measurable quantities. This opposite approach has been in play now for over one hundred years with very frustrating results. The central thrust here is to focus on material reality (the electron) and reject constructing mathematical theories on "nothingness" (or the æther), which must then be integrated across the whole universe. Newton demonstrated the value of introducing powerful local concepts (the mass particle) before introducing new mathematics (*Mathematical Principles of Natural Philosophy*). The expanded study of the history of physics would reward more researchers into the fundamentals of our natural world. As Newton also showed, it is easier to expand the properties of known material objects than it is to invent new, hypothetical entities. This has been the path followed here with the emphasis on interactions **between** objects, rather than imagine that such objects obsess on themselves ("virtual photons").

The present theory has challenged the long-held assumption of the addition of forces. Ironically, this was initially introduced to simplify the effects of multiple interaction sources on a single macroscopic body but when reciprocated (Newton's Law III) with instantaneous forces, it proved impossible to create analytic solutions. Worse, the **three-body** problem was shown to be an unstable system contrary to direct observations of stable astronomical systems. Once again, forgetting history, today's theorists built the **Standard Theory** on the triplet of quarks, simply assuming that these new fictions are stable. The UET, in contrast, has explicitly introduced the Saturation Hypothesis, limiting instantaneous interactions to a pair of electrons. Moreover, the model of finite periodicity between interactions (the *chronon* concept) eliminates the embarrassing infinities that have plagued quantum field theory since its very beginnings. The world is stable and finite - our mathematics must reflect these undeniable facts.

It is appropriate that the body of this paper ends with the rejection of the photon concept. This was an arbitrary invention to explain the mysterious photoelectric effect, seen here as just another series of remote interactions between electrons. It is only the use of field theory that led to the obsession with the quantum wave function as a calculational device to predict very simple atomic situations. The application of statistical thinking to the properties of this function resulted in the idea of bosons, as some form of elementary particle when the situation called for a distinction between existential entities (fermions) and their interactions (bosons). The present theory introduces a massive reduction in the "kinds of stuff" that the world is made from. This simplification will be rejected by most theoretical physicists, who prefer the elegance (beauty?) of their esoteric mathematics than the simplicity of new conceptual thought.

Instead of geometrizing empty space at a universal single moment of time, the remote EM interaction (i.e. 'light') is about synchronizing the interaction between sets of pairs of electrons, each pair at two points in space at two moments of time. Once again, the attempt to replace a dynamic view of the universe with a simple, **static** model that we can 'photograph' in our timeless imaginations has failed; it is dynamic time that defines reality, not sterile space or simple, fixed imaginative models.

8.9 CONCLUDING REMARKS

This paper continues the investigation of the evolution of the foundational ideas of material reality. This realist research programme is firmly entrenched in the particle view of matter, rejecting all continuum concepts. Newton was the first natural philosopher to focus on the quantitative properties of material point particles, aggregating the interactions between all the particles into a single, simultaneous 'force' acting on a single, 'target' corpuscle. This programme identifies the basic particle with the electron, experimentally found to exist only as a point particle. In contrast to Newton's inert matter-spheres, these electrons are now viewed as "*pulsating with possibilities*", interacting **asynchronously** over a universal time-cycle when pairs of electrons are separated across space and time forming an integral multiple of the foundational units of time and space (referred to here as the chronon and luxon) and when both electrons are at their appropriate phase-point. Maxwell was a dedicated Newtonian but could not reconcile the particulate concept with his very strongly held **religious** beliefs that "God was everywhere" (not just where material particles were to be found. This forced him to build his theory of EM on the widely held (at least in the 19th Century) belief on the reality of the **æther**, an unobservable continuous real medium that existed immovably throughout the whole universe. This model is still hiding today behind QED and other QFTs but the embarrassing idea of the æther has been 'subsumed' into the universal existence of mysterious 'force-fields'. One objective of this research programme is to eliminate these hidden, weak metaphysical foundations and ground physics in the verifiable existence of the electron – the true '***master of the universe***'.

8.9.1 PHYSICS, NOT JUST MATH

Theoretical physics has been transformed in the last 100 years or so by recruiting young men who have demonstrated ability in mathematics but have failed to develop as natural philosophers (physicists). These mathematicians have reversed the process that science used to model nature where new imaginative ideas were first proposed and then, when possible, given a mathematical framework. Now equations are sought that will help calculate some numbers that can be compared with experiment (usually after the experiments discovered new phenomena – that is retro-diction, not prediction). These powerful equations are then proposed as demonstrating a one-to-one mapping between their abstract symbols and reality itself. At the macroscopic level, this was quite adequate and was known as **phenomenology**. The problem arose when these equations were introduced to describe a possible micro-reality. As Platonists, mathematical physicists had no problem imagining their immutable symbols **were** the true reality. This is the reification fallacy that has been touched on several times here. This is the explanation for the long war between those who support the particle model of reality and those who believe that waves characterize the natural world. Light rays and waves were the 19th Century version of this metaphysical dispute. They are actually complementary **mathematical** schemes for analyzing theoretical models of optical systems. When viewed just as calculational techniques for computing certain observable numbers these schemes are not a contradiction or paradox but they would be if each were seen as manifestations of reality as these concepts **are** contradictory. Unfortunately, this 'paradoxical' perspective (both for electrons and for light) has also become the orthodox interpretation of quantum reality and given the rubric "*Copenhagen Interpretation*". As a result, physics no longer has a simple model that can stimulate new imaginative insights – the present theory was designed to eliminate this problem and put physics back on track. The role of equations in physics is to provide an elegant and very brief summary of the concepts related by the equation: if the equation can then be manipulated further using the machinery of mathematics, so much the better. But the production of ambiguous (or worse, confusing) equations is **not** the goal of theoretical physics – the history of 20th Century physics illustrates this exceedingly well. The path to understanding nature, which is coherent, is to create a minimal set of coherent concepts that allow humans to continue to think further and deeper on this grand "puzzle of puzzles" – mathematics is **not** an explanation.

Even if this new theory has failed to convince some of its readers of its value it is hoped that (at the very least) it has given them pause for thought. At least to acknowledge that the mathematical theories that have been used for the last 200 years in describing the various phenomena of 'light' do not automatically imply an unchallengeable model of the reality that their mathematical symbols imply. Since most scientists are very conservative in their views, it was necessary to demonstrate that there are alternative explanations to the accepted views of 'light' so that new approaches to atomic and nuclear physics can be investigated with equal confidence, without relying on the well-accepted mathematics or concepts of traditional quantum mechanics and the 'Standard Model' of particle physics. These will be the areas reported on in subsequent papers in this research programme.

Relativity as pure Abstraction (Math)

Planck could never overcome his mathematical predilections; such as in 1909, when he praised Einstein for his modification of the concept of time. "*It need scarcely be emphasized that this new view of the concept of time makes the most serious demands upon the capacity of abstraction and the imaginative power of the physicist, ... non-Euclidean geometry is child's play in comparison*." In 1910, he also acknowledged that progress in solving the abstract problems connected with the Principle of Relativity was largely the work of mathematicians. Wien noted that Minkowski's theory was firmly in the tradition of abstract speculative theories of (mathematical) geometry from Gauss to Hilbert. Modern theoretical physics has been increasingly **hijacked** by mathematicians since about 1900, willingly following the influential Max Planck. As an empirical science, physicists should remember that it is electrons that move (relative to one another) – not reference frames, which are only a useful mental concept when transforming various mathematical schemata.

SRT as a Mathematical Theory

Einstein never acknowledged Maxwell's belief in the æther but he did try to keep the 'light-wave' result from Maxwell's EM theory. Unlike Lorentz (who knew the history of physics better), Einstein rejected the fixed æther in 1905 since the well-known Michelson-Morley experiment failed to confirm its existence. Now he was left with two empty points in space – at the *observer's* origin and at the field point where the expanding spherical light wave was returned back to the origin. Since he had rejected Lorentz's electron, Einstein offered no mechanism for the emission of the light from the origin or for its later reflection from the field point. Indeed, the only physics introduced by Einstein in this 'thought experiment' was the use of *rigid rods* and a 'sea' of *micro clocks* to define the space and time parameters at the field point. Without an electron at the field point, he could just transform the putative, point-like Lorentz force, as if it contained a vanishingly-small point charge (the definition of field intensity) over two instants of time separated by a vanishingly-small time interval, so that he could compute the acceleration and arrive at a new nominal definition of force. This analysis shows that this theory, like all modern field theories, is empty of physical content, especially mass and charge; it is just a set of mathematical equations describing the same empty point in space from two inertial reference frames combined with a new (theoretical) **convention** for synchronizing clocks in motion. Any mathematical scheme following this model **must**, to preserve its own consistency, introduce the Lorentz transformation for its variables – this is **not** the model followed in the present programme.

Non-Reality of Fields or Photons

The authors of the entry on '**light**' in the 1971 edition of the *Encyclopedia Britannica* repeat the orthodox view of light and claim that: "photons and waves are complementary aspects [240] of the same reality." This is not the conclusion of this paper that makes a clear distinction between multiple mathematical schemes for calculating numbers that can be compared with reality in different experimental situations and **metaphysical** models of reality that are proposed as explanations of the existents that form the foundation of nature. Scientific theories that are based on spatial potentials define only a force that **would** be exerted **if** a "vanishingly small" test particle were to be introduced into the field at that point. For any field to be considered 'real' (i.e. representing a physically continuous medium) it should possess other detectable properties than the force for which it was introduced (a failure shared by the Standard Theory with its 'force' bosons). In the 19th Century, this condition was relaxed to the point that finite propagation time alone conferred reality on the field (this then preserved the 'principle of (local) conservation of energy'). In the 20th Century, the reality-condition became centered on the assumed presence of energy and momentum carried by the field itself. It is the **absence** of this feature that distinguishes action-at-a-distance theories. Since all fields in physics are traceable to interactions between real particles, it is pure sophism to view matter as a mere manifestation of a field. It is more intelligible (consistent with the history of physics) to view fields simply as a mathematical construction, **without any reality**, deliberately introduced to reduce the multiple interaction times of two or more bodies to a single local time that is more amenable to traditional mathematical analysis. In particular, the photon concept should never have been viewed as a particulate model of light since no meaning (experimental or conceptual) can ever be given to the position of an individual photon, except at the moments of emission or absorption of electrically charged matter. As philosophers of science have long known, the concept of a unique location at all times, is the *sine qua non* of a **real** particle, whether it is observed or not. Ironically, the founders of QM and their intellectual grandchildren, the masters of QED, where quite happy to forget their positivistic bias when it came to the phenomenon of 'light' and accept the idea of Einstein's photon, although it has never been observed directly. Its reality was grounded only in the reification of terms in various mathematical theories and in the ancient idea that light '**moved**' from one location to another. This tolerance for the particulate reality of the photon was not extended to the particulate nature of the electron, on the grounds that its trajectory inside the atom could not be observed, but it was given a limited existence when it was resurrected as a quantum field. The present theory reverses these views 180° and the next paper will develop a quantum theory of measurement that is centered on the physical reality of electrons and the abolition of all field concepts.

Ockham's Razor

Field theories in physics assume that there is **something** real everywhere, at all times, even in locations where there are **no** measurable things. In contrast, all action-at-a-distance (AAD) theories assume that there is **nothing** between locations where two interacting objects (some-things) really do exist. As a consequence, AAD theories are far more in compliance with the spirit of *Ockham's Razor* – a foundational dictum for simplifying human theories of the world. Field theories are a remnant of the invisible 'mysteries' of earlier religious theorizing. Newton refused to provide a hypothetical explanation for gravity, simply claiming it as a universal property of matter; similarly, asynchronous interactions between pairs of electrons are claimed to be a universal property of every electron. This cyclic interaction grounds the physicality of time.

Space is not an Entity

The introduction of Maxwell's EM field theory coincided with the start of the divorce between physics and metaphysics, whose 'marriage' had characterized natural philosophy from its earliest beginnings. Since Maxwell believed in the reality of the æther, it was appropriate for him to believe that his EM fields were real. The subsequent demise of the æther meant that EM waves had been deprived of their ontological foundation. So that when Einstein continued to accept the reality of EM waves as oscillations in these field values traveling at the same speed in two different inertial frames he was implying a new model of reality, very different from the "things" that humans had accepted as real from time immemorial. When, the interpretation of this theory's mathematics to any 4D "reference point" (x, t) was also claimed to be real and then claim that space and time are subject to the Lorentz transform there was little hope of escaping from this new "*Wonderland*" of the imagination. However, abstract space has always been one of the principal fields of study of mathematicians since ancient times, so it is not surprising that they would promote the mystery of 'space' over the gross materialism of 'electrons'.

UET: a math AND physical model

As Jefimenko has shown, the introduction of the Lorentz transform is needed when the motion of the EM field sources is separated (and ignored) in any field theory that only focuses on the empty field point and further assumes that fluctuations that travel across space at a constant speed are independent of the reference frame. In contrast, in the present theory there are only interactions between real, inertial electrons, where all motion is relative and always independent of any frames of reference; this is a physical theory with meaningful and coherent concepts, not simply a set of mathematical equations.

Redefining Velocity

Since Einstein wanted to keep the speed of light constant across abstract 'frames of reference', he was forced to redefine the **velocity** of any real object, leading to a new formulation of the "relativistic addition of velocities" across multiple frames. This meant that all kinematical and dynamical quantities involving velocity (e.g. distance, time, momentum, energy) had to be redefined. Only a mathematician (and all modern theoretical physicists) could accept this gross distortion of natural philosophy, which is grounded in the empirical observation of changes **between** real objects (and commonsense). The core of this problem can be traced back to Newton's 'trick' of defining instantaneous velocity, at every moment of time, as the mathematical limit of a mathematical ratio; an ideal that is never actually measured in real experiments. This foundational error is analyzed more completely in the next paper in this series.

8.9.2 SCIENTIFIC CONTINUITY

New Properties, not new Entities

It has longer been considered a superior philosophical approach (e.g. Ockham's 'razor') to propose a new property for an existing entity (like gravity or 'spin') rather than inventing a completely new entity. Thus, UET rejects the concept of the photon as a fundamental entity and simply creates a more detailed view of the interaction between electron pairs. Later, a **dynamical** model of **inertial mass** will be presented rather than inventing another fictitious field – the Higgs boson.

Neo-Newtonian Physics

In recognizing the fundamental contribution of electrons to the natural world, UET expands on the inert billiard-ball model of classical Newtonian particles by adding dynamic factors that introduce new, "pulsating possibilities" and active, "choice-like" decisions, via selection rules (usually associated with living creatures). So that all matter now appears "**alive**" – this unifies all levels of the material world – "from electrons to elephants", restoring the ancient Western Hermetic intuition with the Eastern philosophies of the world. This removes the ancient (and arrogant) distinction between living and lifeless matter.

Restoring Universal Time

The present theory rejects the modern acceptance of Einstein's notions of space and time. Here, based on the fundamental idea of the electron interaction, space is defined traditionally in terms of line-of-sight optical triangulation, while clocks are synchronized, in all directions, by explicit delay times using the universal space-time constant: $\Delta x = c\,\Delta t$. The rate of time evolution is universal, based on the universal electron interaction cycle of the **chronon** – whether objects are stationary or moving past 'fixed' observers. The idea of 'observers' was always a mathematical convention to define reference frames.

Replacing LaPlace's Determinism

This new theory replaces the classical concept of **determinism** (where events in each particle's past uniquely determine all current behavior) with the concept of "***coherence***" – a condition where all activity in the universe (everywhere and every when) is consistent. All other interactions that an electron may participate in, viewed from any time point in its eternal existence (both in its own past and its own future) are necessary and sufficient. The interaction selection rules at any instant force an electron to interact with (at most) one other electron across time but the electron is still 'aware' of every electron's position and status every-when. Active 'signaling' is only the macro-averaged retarded interaction with our own past. This does **not** imply that electron trajectories are "determinable"; i.e. predictable by human beings, but why would Nature care?

8.9.3 CONCEPTUAL SIMPLICITY

Respecting Ockham & Hume

William of Ockham's Principle of Conceptual Simplicity (or Ockham's *Razor*, stating that: "natural philosophers should not multiply entities beyond necessity when investigating new phenomenon") is respected in the present Universal Electron Theory (**UET**) wherein there is only one entity posited: the electron. The idea of a shared, asynchronous action-at-a-distance (ADA) between two electrons also eliminates David Hume's inductive skepticism because in UET there is no strict causality: every macro event is always contingent on the context of **all** the micro-events involved.

Abolishing the Æther (only electrons are real)

UET is constructed from a massive simplification in the fundamental concepts from which it is constructed. It may be summarized by stating: "**Only electrons exist, while light occurs.**" This is the basic metaphysical hypothesis (ontology) that forms the foundation for the whole theory. In extended form, it means that only electrons are the permanent entities in the real world whereas, although light is a real phenomenon, it is a dependent contingent process that may occur sometimes **between** pairs of electrons. In contrast to other fundamental theories of physics (e.g. QED, quantum gravity, the Standard Theory), UET posits **no** unobservable entities (e.g. photons, strings, quarks, etc.): only new rules to describe the **interaction** between electrons, whose **existence** is beyond dispute.

Eliminating Multiple Wave Modes

As described in section 3.5.2 above, the present asynchronous action-at-a-distance theory, by treating waves as only limited mathematical approximations when calculating outcomes in optical situations, eliminates the need for viewing various modes of wave activity as real when considering the reality of emission, transmission and absorption of light. The extended discussion of significant optical phenomena, such as diffraction in section VII, was included to demonstrate that wave mathematics is **not** the only way to analyze the 'mysterious' interference effects of 'light'. The answer then determines if the mathematics of waves would simplify the calculation of effects or whether a particle-like analysis is better.

Eliminating Waves AND Particles

The UET theory of the electron interaction resolves the long-standing debate on the nature of light (wave or particle?) with the answer – **neither**. A 'photon' is here viewed as the nominalism introduced to describe the situation where two electrons exchange one set of consecutive interactions. A 'light-wave' is the shorthand used to refer to the collective or average effect of many interactions between numerous electrons. Thus, this ancient debate is resolved in any real situation by asking the question: does this particular experiment observe the effects on **one or many** electrons?

Eliminating Light's variable Trajectories

The idea that light is an entity that travels independently through space leads to the illogical proposition that the trajectory taken between its emission point and its absorber depends on the frame of reference from which it is viewed. So, a simple reflective 'path' in one reference frame becomes an infinite number of triangular paths in all the other inertial frames that are moving at constant speed relative to the reflecting object: this must be viewed, at best as an optical illusion and most likely, as simply a mathematical expression that has no observable consequences. Feynman foresaw these many 'paths'.

Eliminating variable Time in relative Motion

The point of "Einstein's Express" is not that the observer at the center of the super train observes the two lightning flashes occurring at a different times than a fixed observer on the platform (he won't). The real issue is whether the clock-rate (i.e. time intervals) for observers on the train is different from the rate observed on the platform. The actual number displayed on the clocks (called by us: "time") is simply a convention, just as it is for a second, fixed observer at a different location along the platform, who is being passed when the train passenger passes him. As was discussed extensively in UET4, even though electrons may 'tick' at a constant universal rate, independent of their state of motion, this does not mean here that electrons in different, relative motion will be at suitable points in their send/receive cycle to be on their mutual light-cones. It is this synchronization of the possibility of interaction when in different relative motion that leads to the apparent changes in "clock" rates. It is not that time runs slowly in these situations but the ability to effect an interaction that varies. Only human arrogance (or Positivists) would confuse the nature of reality and our ability to measure (assign numbers) to it.

Independent of Observer Motion

It is not space and time that are 'weird' (requiring the Lorentz transform to distort all physical intervals) but Maxwell's (and Einstein's) model of light that was wrong when light is considered a one-to-one mapping between its symbol set and reality. Asynchronous action-at-a-distance between real point electrons removes this distortion that was only introduced by mathematically 'throwing away the source' and focusing on empty points in space, i.e. geometry (the 'sacred science').

8.9.4 A NEW FOUNDATION FOR QUANTUM THEORY

The duality of particle and wave characteristics introduced by alternative mathematical representations of light phenomenon has been the foundation for a similar duality at the center of quantum mechanics. This programme cannot accept that reality suffers from this paradoxical duality (the 'Copenhagen Interpretation') and believes that only when physics is grounded in a coherent, non-contradictory set of concepts can progress be made at the fundamental level. The present theory is designed to present a unified model at both the conceptual and mathematical levels, which can be visualized by any human being to stimulate new intuitions that have always been the basis of real progress. QM is critically reviewed in a later paper.

Everything Connected Serially

The mechanism of **saturation** developed here means that the assumption of the vector addition of forces is abolished. Over time (and hence averages) will see a series of pairwise impulses accumulate the total effects **on** a single electron. This process eliminates the pernicious effects of multiple, simultaneous interactions between more than two bodies (the infamous **three-body problem**). This will be demonstrated later in models of multi-electron atomic scale systems.

8.9.5 FAMOUS FINAL THOUGHTS ON LIGHT

Newton: Optickal Confusion, from the Beginning

Science is no further ahead today in understanding the nature of light than when Newton first published *Opticks* in 1704. As noted Newtonian scholar, I. Bernard Cohen writes in the preface [241] to the Dover edition: "*This masterpiece disappeared from print for 150 years until 1931 because Newton had backed the wrong horse [the corpuscular theory] since the general feeling in the 19th Century was that the wave theory of light was the only true explanation of optical processes*.". Dr. Cohen credits Thomas Young with revival of the wave theory in 1802, when he invented the principle of destructive interference to explain the dark fringes found in diffraction. This was reinforced by the suggestion that light was purely a transverse motion (that explained polarization) and the researches of Fresnel and Arago in France. Ironically, *Opticks* was read much more by non-scientists; not just because it was written in English but also because it described real experiments and contained little mathematics, in contrast to the scholarly *Principia*. Newton was confused and tried to merge wave and particle concepts but this was not a precursor of the photon theory but an early awareness of the contradictions of using human-scale metaphors.

Newton rejected the wave model of light for various reasons, not least because of the analogy of dropping a stone into still water resulting in a spreading wave everywhere, but he could not see how this would result in the kind of rays he was using from holes in his window blinds. He also was committed to the idea that colors of light were related to differences in periodicity (frequency) and Huygens' impulse model lacked any periodicity. He could expand his corpuscular theory of light by linking it to stimulated disturbances in DesCartes' well-accepted model of the æther that consisted of even finer particles that propagated effects between themselves. These ancient Cartesian ideas underpinned the ætherist models of light and Maxwell's own thinking.

Maxwell: Light needs the Æther

In his famous *Encyclopaedia Britannica* article on "Ether", Maxwell defended his view of Huygens' "luminiferous æther" (this older spelling was used throughout the article). Firstly, he used the null effects of destructive interference to dismiss the suggestion that light is a "substance" since he cannot imagine the annihilation of two bodies when they are "put together". He identified the positive and negative characteristics of interference as the signature of a "**process** going on **in** a substance." He subsequently concluded: "*we may use the term æther to denote this medium."* He simply affirmed that this medium transmits energy with finite time delays so that the energy *"exists for a certain time **in** the medium*." Claiming to adopt either Fresnel's or McCullagh's forms of the undulatory theory he wrote: "*we must therefore regard the æther as possessing elasticity similar to that of a solid body and also having a density (about 10^{-18} gm per cubic cm; vastly greater than that of interplanetary space)*." He ends with the speculation that this æther is homogenous and continuous, as regards its density but may be rendered heterogeneous by its motion, as in Thomson's vortex molecules in a perfect liquid but admits that: "*no theory of the æther has yet been invented*." It must also be noted that no such medium has ever been observed.

Einstein: Contradictory Ideas

As Einstein wrote in [242] 1951 to his life-long, best friend, Michele Besso: "*All these last 50 years of pondering have not brought me any closer to the question – What are light-quanta?*" Einstein was always disturbed by the dualism present in Lorentz's Electron Theory, which married Newton's particle mechanics of the electron [243] with Maxwell's field theory. Einstein pointed out the crucial difference in mathematical techniques between these two types of theory near the end of his own life: "*The weakness of the Lorentz theory lies in the fact that it tried to determine the phenomena by a combination of **partial** differential equations and **total** differential equations, which procedure was obviously unnatural*." [244] Einstein was alluding to the fact that field theories, like Maxwell's, use the partial time derivative while particle-particle theories, like Newton's, use total time derivatives. Partial time derivatives only make sense when applied to a continuous medium (or empty space) but total time derivatives are used when a material object changes its properties, including location. However, earlier in this same book, Einstein had justified his light-postulate through his confidence in Maxwell's Equations: "*Light speed in a vacuum has a definite and constant value, independent of the velocity of its source. Scientists owe their confidence in this proposition to their acceptance of the Maxwell-Lorentz theory of electrodynamics.*" Strange that a physicist would build his own theory on another theory with acknowledged flaws and even more strange that he would **not** attempt to lay his foundations on firmer empirical evidence. However, metaphysical fashion throughout history explains how these giants of physics can be bowled along by the group opinions of their peers. The atomistic model was popular with Newton's English rivals, while the continuum thinking of the plenum (or æther) dominated in the 19th Century; today it is the field model that is viewed as the supreme answer for most theoretical physicists (but not to this author).

Pauli's 'noteworthy duality' Paradox

In his lectures on electrodynamics, Pauli concludes with the following discussion: "*If light is emitted and then absorbed then the conservation laws for kinetic energy and mechanical momentum are valid after the absorption. Without associating energy and momentum with the electromagnetic field, these conservation laws cannot obtain at each instant of time between emission and absorption. However, it seems unnatural to eliminate the field since it is not apparent why more reality should be ascribed to the material particles than the field*." But Pauli then goes on to say: "*that the equations for a perfect vacuum (where $\rho = 0$ and $\underline{J} = 0$) are only an idealization, since electromagnetic fields can be produced and detected only with the use of mechanically describable particles that carry charge.*" Pauli describes this EM paradox with the comment "*a noteworthy duality*" [245]. As a great man of his times, Pauli's commitment to the concept of the field was too foundational to challenge and as a mathematician, the continuum mathematics used in physics was just too elegant to forgo.

Dirac: Fields based on Instant Forces

Dirac recognized as early as 1927 (in his introduction to his first paper on radiation) that the Hamiltonian approach could **not** be used for asynchronous forces: "*The new quantum theory ... can only treat the problem of any dynamical system composed of a number of particles with instantaneous forces acting between them, provided it is totally describable by a Hamiltonian function. The questions of the correct treatment of a system in which the forces are propagated with the velocity of light, where the EM field is produced by a moving electron, which is reacted upon by this field, have not yet been touched*." [246]

Planck: We can't ignore the Source

In his final essays on physics, Max Planck writing about the conflicting theories on the nature of light said that: "*At the present, this position is an exceedingly unsatisfactory one. It is probably correct that neither theory will prove completely victorious. It is more likely that in the end a higher standpoint will be reached, where we shall be able to survey clearly the claims and deficiencies of each of the two hypotheses*." He expects that: "*optical laws can be completely understood only when the peculiarities of the process of measurement as well as the **physical events** at the points where the light originates and spreads are fully considered.*" [237]

8.9.6 SUMMARY: "AN OPTICAL MANIFESTO"

Optics has been central to physics since Newton's time. It has stimulated the creation of the **technology** for extending man's most powerful sense to observe both very large distances (the telescope) and very small spatial separations (the microscope). This ability to observe the micro-world is a direct consequence of the extremely rapid fluctuations in time (about 10^{14} / sec.) for many of the sources of visible light.

The history of the theory of light demonstrates the great utility of **harmonic** analysis. Once again, the mathematicians have simplified their approach to physics by reifying their mathematics and interpreting the physical nature of light as the reality of waves: first in the æther and later, as abstract fluctuations in electromagnetic force densities. The studies of interference and diffraction were sufficient to convince most scientists of the reality of waves as the basis for light. The observation of the **photoelectric** effect and subsequent interactions between light and matter challenged this ancient view, leaving modern physics with a metaphysical contradiction in its physical understanding of the real nature of light: local particle or universal wave?

The present research acknowledges the utility of the mathematics of waves but rejects this modern paradox, viewing light as the remote **interaction** between several electrons, always viewed here as localized **point** particles. This paper has presented a new theory centered on extending the electromagnetic interaction, not in terms of field theory but involving exchanges of discrete information **and** momentum between pairs of electrons. The Saturation Hypothesis was shown here to be sufficient to account for the observed optical effects that have been attributed to wave combinations for over 200 years.

Too many modern theoretical physicists still reject philosophy and tell us to "*just calculate*" (proudly boasting of the accuracy of their mathematical predictions with observed experiments). One needs to remind them that a similar short-sighted dismissal of the physical hypothesis of Copernicus by the Ptolemaic claim of much better predictions of the next appearance of Venus (true) would never have given the world the revolutionary physics of Newton. The *Principia* not only provided a new mathematical approach but it was constructed upon his ontological proposals for new properties of matter corpuscles. This demonstrates that new concepts drive real progress in physics, **not** mathematical techniques or deductions.

8.9.7 SO, WHAT IS LIGHT?

The fundamental question surrounding this subject is: "**what is light?**" The theory presented here is that it is **not** a basic **entity** (or substance) of nature but different perspectives on the fundamental interaction between the foundations of reality – the **electrons**. When **two** remote electrons exchange energy and/or momentum through a series of consecutive interactions then those phenomena associated with the idea of a 'particle of light' (or photon) occur. When **many** electrons interact with one or more remote electrons through a correlated set of interactions then those phenomena associated with the idea of a 'wave of light' occur. Thus, ***light is the covering term for several different types of interactions between electrons – some involving only one pair of electrons and others, very many electrons***.

As 'light' is now viewed here as a **process** it is no longer a contradiction (or 'paradox') to consider this process to have characteristics of both locality in space (particles) and variations in time (waves). There is no longer a mysterious entity that **is** sometimes a particle and sometimes a wave (the 'Copenhagen' interpretation of quantum mechanics) but the interaction between localized particles has time-sensitive characteristics. The free-floating unreal model of 'fields' is no longer needed.

The present theory picks up the challenge that Richard Feynman set himself – develop a new theory of electromagnetism that is self-consistent and finite. This new theory is based on the original vision of Wheeler and Feynman, who (like Dirac) always took the electron as primary while viewing the EM field only as a mathematical and statistical construct, all EM interactions [247] are between **different** electrons, with **no** self-interactions.

In the present theory, all **infinite** concepts are rejected, including: summations over infinite space and time, continuous density quantities, continuous forces, infinitely close or instantaneous interactions. The new theory builds on Feynman's space-time model but rejects his mathematical approach that allowed electrons to roam everywhere across the universe at infinite speeds. The rejection of a **single-time** representation (assumed by all local field models) eliminates the idea of continuous potential functions that have been at the heart of all mechanical theories and form the starting points for both Hamiltonian and Lagrangian techniques. The rejection of the concept of the **field** (and Maxwell's theory of EM as a foundational viewpoint) means the elimination of the Lorentz transformation, as it becomes an irrelevant "equation constraint" in two-time theories. Rejection of the EM field hypothesis (and the "Lorentz force" [248]) and its quantized versions means that the photon concept is also eliminated. This is replaced by the central role of the exchange of information between all electrons that determines the cyclic pair-wise asynchronous exchange of discrete quantities of momentum. Electrons are now seen as the **eternal** point particles defining all aspects of material reality while the vacuum reverts to its Newtonian role as simply the absence of all matter; there is therefore [249] no vacuum polarization in this theory and therefore no virtual particles or mathematical infinities. The idea of infinity has bedazzled Platonists for over 2500 years, when this is combined with the mysterious properties of empty space then a religious awe too often overtakes too many mathematical physicists, who deceive themselves by thinking they are only studying geometry.

8.9.8 NEXT STEPS

Feynman: Defends Space-Time Approach

In describing his "*Space-Time Approach to QM*", Feynman acknowledged that no new results of this formalism had been discovered (to date) but he did say that approaching old problems [250] in a new way had its own intrinsic value. It is from this perspective that the present paper has revisited the old problems of light, laying the foundation for new insights in this programme's subsequent papers. In his Nobel Prize speech in 1966, Feynman believed that multiple theoretical approaches to the same problem were always justified, even if all their predictions agreed exactly, because they are not psychologically identical since different views suggest different kinds of modifications that might be made resulting in different hypotheses for achieving greater understanding of the unknown. It is in this light that the present programme is undertaken. Indeed, Richard Feynman, who loved his theory of QED, has to be acknowledged as another hero of this story into man's long-term search to understand the nature of light. He was right to state that: "*the interaction of light and electrons is the part of physics that we know best*" but since he also wrote that: "*Nature is generally incomprehensible to us*" [251] it behooves physicists to revisit this key area of science to clarify our fundamental concepts so that progress can be re-established on firmer foundations. The phenomena of light have been at the center of physics for hundreds of years and still lurk behind the modern puzzle of quantum mechanics. Indeed, Feynman's QED is a direct descendent of Huygen's mathematical construction, both relying on the imagination of secondary waves originating everywhere in empty space.

Einstein wrong about Light

Einstein was wrong about the nature of light; even though he tried to create a physics theory with contradictory concepts: light is neither a wave (special relativity) nor a particle (photon) but an interaction between electrons. Unfortunately, this ability to believe that logical contradictions can be used to describe a singular element of reality has become only too well accepted in physics, now that philosophy has retreated from this primary area of knowledge. The wide acceptance of the contradictory 'Copenhagen Interpretation' has meant that quantum mechanics is still "*on shaky ground*". This will be the focus of the next paper in this series, when the **measurement** of electron activity is analyzed in extensive detail. It should be obvious that two different mathematical schemes can be used to describe the actions of the same ontological object when it appears in different contexts - but positing contradictory characteristics of the same object leads to deep mental confusion.

The next paper will pick up the 'story of the quantum' but re-emphasize the absolutely central role of the electron in physics – Feynman's space-time model will be given a firm physical foundation. This will introduce realistic constraints that will be shown to **eliminate all infinities that have plagued QED** for eighty years and provide a realistic interpretation of the quantum measurement problem. The following is a brief summary of the remaining papers in this research programme.

UET7: Quantum Electron Mechanics (QEM1)

This paper is the complement of the present Theory of Light; it extends the new approach to a quantum theory of electrons. The focus is on the connection between the micro-world, when left to itself, and our mental models of this sphere via the mechanism of measurement. It provides an unambiguous model of macroscopic **measurements** of the micro-world. This paper will provide a unitary (particulate) explanation for all the atomic-scale experiments that have generated the crazy idea that an electron exists as **both** an electron and as a wave.

UET8: Atomic and Molecular Electron Mechanics (QEM2)

This paper applies the results of its three predecessors to the analysis of simple atoms and molecules. These techniques overcome the "**3-body**" barrier that has blocked analytic extensions of quantum mechanics to the multi-electron atoms, such as helium etc. Energy levels are calculated algebraically for each of the atoms from hydrogen to neon. Simple, multi-atom molecules, such as hydrogen, oxygen etc. are also analyzed with these new techniques. All these systems have resisted QM.

UET9: Particle Electron Mechanics (PEM)

The Universal Electron Theory (UET) is extended to the realm of the sub-atomic particles. All-electron models of the three **neutrinos** and the various **mesons** are proposed. This analysis includes a new dynamic model of mass (without Higgs) so that algebraic calculations of particle masses can be developed *ab initio*. Additionally, a new model of the **electro-weak** force is provided that avoids all hypothetical quantum fields, such as the W or Z "particles". A new mechanism for electron-positron **pair creation** is also presented, which preserves the eternal existence of both positive and negative electrons.

UET10: Nuclear Electron Dynamics (NED)

This paper extends the discrete version of this EM interaction to the scale of the nuclear particles. New models of the proton and **neutron** are proposed that consist only of positive and negative electrons that avoid all use of field theory. The 'strong' force is shown to be a very short-range, saturated version of the new EM impulse developed earlier in the programme. A new interpretation of the so-called **quark** model is proposed. The dynamical model of particle masses is used to calculate the mass of the proton and the neutron, which agrees with observed values.

UET11: Gravitational Electron Mechanics (GEM)

An all-electron model of **gravity** is proposed that avoids gravitons, fields or 'bending of space' or other exotic creations (e.g. 'dark matter'). Explanations of light-bending and other bizarre effects are included.

8.9.9 EPILOGUE

It seems appropriate at the end of this revolutionary treatise on light to quote another rebel, who resisted the overwhelming move to support the wave theory of light. The following quote is taken from the preface of Professor Richard Potter's classic book on Physical Optics [228], where he tried to defend the corpuscular theory of light molecules: "*The expressing in mathematical formulae in the interference of ordinary and polarized light acted like an enchantment upon the mathematicians. ... With such advocacy, it was not likely that the author of the present treatise would find companions in investigating critical points where the undulatory theory fails. ... The author hopes that his long perseverance against dogmatic error will not be considered as lost labor by future investigators.*"

As Max Planck wrote ruefully [252] near the end of his life: "*If a new idea were to be admitted only when it had definitely proved its justification, or if even if we merely demanded that it must have a clear and definite meaning at the outset, then such a demand might gravely hamper the progress of science.*"

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[175] see ref [5] [Spencer] § 4.1.6
[176] see ref [5] [Spencer] § 4.1.6-7
[177] see ref [5] [Spencer] § 6.2.1
[178] see ref [3] [Spencer] § 7.9.1
[179] see ref [3] [Spencer] § 7.6.1
[180] see ref [170] [Mead] p. 7
[181] see ref [3] [Spencer] § 7.6.3
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